Improving the Urban Ecology of Northern Waller Creek through Citizen Implemented Green Infrastructure to Benefit Pollinators

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by

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Dedication

This thesis is dedicated to my partner Jimmy, for his unwavering love, commitment, and tolerance of my emotional instability throughout the production of this thesis. My cat Calypso, for her unconditional love. My friends, for their support and timely distractions. And my parents, for without you I would not be where I am today.

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Improving the Urban Ecology of Northern Waller Creek through Citizen Implemented Green Infrastructure to Benefit Pollinators

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The University of Texas at Austin, 2018

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What pollinator-focused green infrastructure designs are most likely to benefit the urban ecology of Waller Creek, an urban creek in Austin, TX given its unique social and environmental characteristics? This research aims to accomplish three things: 1. Better understand strategies to create successful green infrastructure that supports pollinators; 2. Understand obstacles and motivating factors for stakeholders who wish to implement pollinator-focused green infrastructure; 3. Provide guidance to help people implement successful green infrastructure that supports pollinators and synergy between people and their urban ecosystem. This study analyzes case studies of pollinator-focused green infrastructure, conducts interviews with professionals in fields related to pollinators, community engagement, or green infrastructure, surveys stakeholders of the Northern section of the Waller Creek watershed, and creates two designs of pollinator-focused green infrastructure to provide visual guidance to those wishing to

implement similar projects. The goal of this research is to better understand what people can do to ensure the vitality of urban ecosystems and to encourage citizens to become stewards of their environment. This thesis also expands on the notion of social systems as a vital part of green infrastructure interventions and the need for civic environmentalism to support small-scale green infrastructure. By establishing multiple small pockets of pollinator-focused green infrastructure along Waller Creek and encouraging more pollinator friendly maintenance methods we can create a pollinator corridor with the creek as the spine.

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CHAPTER 1: BACKGROUND

Introduction

As human populations continue to grow and move into ever sprawling cities, urban ecosystems are becoming increasingly important. This research addresses what pollinator-focused green infrastructure designs are most likely to benefit the urban ecology of Waller Creek, an urban creek in Austin, TX given its unique social and environmental characteristics? Using mixed research methods, I analyze how green infrastructure can be effectively designed and maintained to provide ecosystem benefits to the urban ecological fabric of Waller Creek. This research aims to accomplish three things: 1. Better understand strategies to create successful green infrastructure that supports pollinators; 2. Understand obstacles and motivating factors for stakeholders who wish to implement pollinator-focused green infrastructure; 3. Provide guidance to help people implement successful green infrastructure that supports pollinators and synergy between people and their urban ecosystem.

Most people today live in cities and urbanization is a megatrend that is expected to continue throughout the world at least until mid-century (UN

Habitat, 2006). Urbanization has been characterized as "a massive, unplanned experiment in landscape change" (Niemela, et al., 2011) leading to significant conversion of land to urban development. This urbanization is unprecedented and emphasizes the need for innovative approaches to generating knowledge before, during, and after the process of urbanization in an adaptive mode. Thus, new approaches to urban planning and design will be increasingly important to address the challenge of sustainable urban land use (Keely, 2007).

Austin, Texas's topography and urban fabric are defined by the many creeks that bisect the city. The bodies of water between which the city was founded still form the informal boundaries of the central business district, paying tribute to their importance. The watershed for Waller Creek exists entirely within the boundaries of the city of Austin. Waller Creek wanders through what can be considered the heart of Austin. It touches many important features from Lady Bird Lake to The University of Texas at Austin to historic neighborhoods in Austin. Given that green infrastructure is context driven, how will pollinator-focused green infrastructure design and maintenance strategies change depending on the adjacent urban context and user requirements?

Over the years, the city and its residents neglected and degraded these urban creeks. Important strides have been taken to improve the health of these creeks, though many are still human impacted ecosystems. Urban ecosystems provide many benefits to humans as well as plant and animal life through ecosystem services. Ecosystem services are the benefits and services provided by nature that facilitate life. These services can be broadly divided into four categories: provisioning services such as food and water; regulating services such as flood regulation and pollination; supporting services such as soil formation and photosynthesis; and cultural services such as recreational and spiritual benefits (Millennium Ecosystem Assessment, 2005). As urbanization spreads there are fewer agricultural and natural landscapes, placing greater importance upon urban greenspaces to provide the ecosystem services that were once being provided by rural landscapes.

Implementing green infrastructure which benefits pollinators along Waller Creek will also have positive effects on the local urban ecology due to the multifunctionality of green infrastructure. Small-scale green infrastructure projects in which citizen have a vested interest are a comprehensive and faster way to bolster the urban ecosystems of Austin without contributing to sprawl. As

cities densify and grow, there is less space for new, large green spaces within urban areas. In addition to preserving the already existing open space, citizens should implement their own small scale green infrastructure projects in underutilized areas to boost urban ecological health and connectivity. A network of self-implemented, micro projects nested within a larger metropolitan green infrastructure plan from the city will reinforce urban ecological health. This way the issue of ecological health in the city can be address from both an institutional level and a private, smaller level.

The City of Austin is currently exploring the concept of citizen maintained green infrastructure along Waller Creek. Implementing small-scale green infrastructure across the city would create too much strain on municipal systems for it to be practical. However, if citizens could maintain their own small infrastructure and only rely on the city for funding and guidance then this mass of small projects could be feasible. Therefore, it is important to understand what are the most common obstacles, perceptions, and motivating factors when implementing pollinator-focused green infrastructure. Implementing pollinator-focused green infrastructure within the underutilized green spaces along Waller

Creek will create a habitat corridor running through the heart of Austin without contributing to sprawl.

For the purposes of this research, green infrastructure can be defined as "natural, semi-natural and artificial networks of multifunctional ecological systems within, around and between urban areas, at all spatial scales" (Tzoulas & James, 2010, p. 169). However, to continually deliver these ecosystem services, green infrastructure must not only be physically and temporally planned but also require continuous engagement among invested people lest the project become forgotten and neglected. The living components of green infrastructure constantly face new threats and need long-term maintenance to survive (Lindholm, 2017). Unlike traditional grey infrastructure, green infrastructure has a maturation period wherein plants are more fragile until they take root. Even when mature, living systems within green infrastructure require maintenance and protection from harsh conditions. This necessitates cooperation among different public administrations as well as between private and public stakeholders in a transdisciplinary manner to ensure the success and longevity of the project. Although the project owner should conduct a majority of the maintenance, often projects become overlooked and neglected by institutions. This is why volunteer

events that clean public parks or roadsides are so ubiquitous. Institutional support is essential for projects to survive but private stakeholder support ensures that projects are not left behind.

Design is any intentional change of landscape pattern for the purpose of sustainably providing ecosystem services while recognizably meeting societal needs and respecting societal values (Nassauer & Opdam, 2008). Often due to the siloing of departments within design firms the building is created before planning the surrounding site. When landscape is an afterthought, ecological function is deprioritized. Incorporating green infrastructure into the early process of design at all scales, from the building to the regional scale. Green infrastructure plans should be nested within each scale, creating a larger comprehensive network boosting ecosystem services. At each level of analysis, as one moves to a smaller scale, a new intricacy of a plan should make itself apparent, creating a layering of micro-plans nested within regional plans.

Since transdisciplinary efforts are required to ensure long-term maintenance and project health, I propose that educational outreach or social systems be incorporated in this definition of green infrastructure since they are essential for generating public interest and civic environmentalism. Like any

architectural or landscape design, green infrastructure is context dependent, so we can assume that applications will be different depending on the surrounding typologies (Lindholm, 2017). Specific designs for pollinator-focused green infrastructure will likely differ between sites near residential homes, schools, or public park space as physical constraints and user requirements change.

Several applicable lessons have been learned from the data collection and methods of this research. First, green infrastructure that supports pollinators should be implemented in underutilized spaces so as not to contribute to urban sprawl. Second, long-term maintenance is required for successful green infrastructure. Based on this research, I recommend creating a maintenance plan ideally involving both project owners and volunteer groups before the project is developed. Through case study analysis and professional interviews, it seems the best way to plan for maintenance is to incorporate safe-to-fail strategies like relying transdisciplinary cooperation usually between local communities and city government is needed for long-term maintenance. Leadership and group hierarchy of volunteer communities are important for lasting maintenance and for establishing effective communication between different groups.

After this research, I would recommend that civic environmentalist groups involved in green infrastructure projects undergo some leadership training and perhaps gardening training as well. Resources for such trainings are included in the guidance handout. The third lesson is that community engagement must be done properly for it to be useful. Educational outreach is key for public buy-in, support of the project, and the incorporation of safe-to-fail maintenance. Finally, when designing pollinator habitat is it important to plan for biodiversity, design for the entire lifespan of a pollinator, pay attention to soil and sunlight conditions, plant clusters of flowers that are a meter wide, target specific pollinator species, understand the user's tolerance for "messy" landscapes, and provide year-round necessities for pollinators including dietary variety.

This thesis identifies existing gaps in the literature about green infrastructure regarding pollinators, explores the differences in design of green infrastructure in various contexts, and contributes to the body of knowledge about how social systems and civic environmentalism can play essential roles in the success of green infrastructure in urban ecosystems. This report will first review literature related to pollinator-focused green infrastructure, then outline the research design and methods used in this study, discuss findings from case

study analysis, interviews, surveys, and experimental site designs, and then finally provide guidance for communities in Northern Waller Creek to establish and maintain their own pollinator-focused infrastructure.

Literature Review

Multiple bodies of literature have informed the work of this thesis. A review of the literature pertaining to green infrastructure aims to examine the relationship between the urban environment, including human systems, and green infrastructure. Since most of the literature regarding green infrastructure focuses on stormwater management (Hansen, 2013) (Lee, Bae, & Younos, 2018) (Kim & Li, 2017), this research identifies a gap in the literature addressing the use of green infrastructure to support pollinators. An analysis of literature regarding ecosystem services, particularly pollination, identifies relatively new applications of green infrastructure being used to bolster urban pollinator systems. These applications are further explored in the case study analysis. A better understanding of what people can do to ensure the vitality of urban ecosystems is the goal of this research. The urban/human ecology nexus is analyzed to ascertain the relationship between green infrastructure strategies, the surrounding built environment, and social structures given that green

infrastructure adapts to its surrounding contexts. My research also expands on the notion of social systems as a vital part of green infrastructure interventions and the need for civic environmentalism to support small-scale green infrastructure.

Green Infrastructure

Despite the rising popularity of green infrastructure, the topic remains quite broad and elusive. The abundance of research on water-related green infrastructure is only tangentially applicable to my research due to the proximity of Waller Creek. Very little research has been done regarding the effects or design of pollinator-focused green infrastructure. Although, green infrastructure is inherently multifunctional and multiscalar, (Cortinovis & Geneletti, 2018) (Benedict & McMahon, 2002) (Lennon & Scott, 2014) (Ahern, Cilliers, & Niemela, 2014), I only examine green infrastructure that would directly benefit pollinators. Overlapping ecological benefits will be explored wherever possible, but directly limiting the benefits allows for better control and management of the scope of this research.

If we think of green infrastructure as not only physical interventions to support ecosystem services but also maintenance techniques and social structures that ensure the longevity of projects, then I propose that social systems also be considered as green infrastructure. There is abundant research that explores the need for long-term maintenance in order for green infrastructure to succeed (Rinas, 2014) (Décamps, 2001). For green infrastructure to be successful, it must incorporate or respond to the surrounding contexts and be maintained and monitored by groups of people invested in the wellbeing of the project and surrounding communities. The effects of green infrastructure cannot occur without: regard to the existing conditions before the intervention, adaptation to the local context and site-specific factors, long-term visions, as well as maintenance requirements and adaptation potential (Lindholm, 2017). Green infrastructure must consider context to be effective; there is never a one-size-fits-all solution for complex problems. Therefore, it stands to reason that green infrastructure designs for schools which are vacant during the summer will differ from designs where year-round maintenance can be achieved.

Green infrastructure in urbanized areas must take a broad, holistic perspective to avoid creating unintentional environmental injustices. Approaching

green infrastructure through the lens of ecosystem services creates an innovative planning strategy that dynamically captures social–ecological systems in urban areas and supports policy objectives such as sustainable development, environmental justice, social cohesion, or resilience. Green infrastructure planning that takes a holistic approach appears to be especially well suited for urban areas as these areas can be characterized by a dynamic interplay of social and ecological systems. However, equitable access to any added benefits should be considered to avoid unintentional increases in environmental injustice (Hansen & Pauleit, 2014).

Research indicates there is a direct relationship between green spaces and human health (Dunn, 2010) (Tzoulas, et al., 2007). This relationship between greenspace and social support is strongest in urban communities and for youth, the elderly, and persons of low socio-economic status, all of which are believed to have lower levels of mobility (Coutts & Hahn, 2015). Urban areas tend to have less overall greenspaces compared to rural or suburban areas, however the addition of green spaces can lead to unintended ecological gentrification. Ecological gentrification can be defined as the implementation of an environmental planning agenda related to public green spaces that leads to the

displacement or exclusion of economically vulnerable human populations while espousing an environmental ethic (Dooling, 2009, p. 630). This displacement can be achieved through the explicit exclusion or removal of people experiencing homelessness or through increasing property values forcing economically disadvantaged people to relocate. In addition to ensuring that access to implemented green infrastructure is equitable for all communities; planners and designers also need to be cognizant of any unintentional ecological gentrification that may result from implemented designs.

Ecosystem Services

Due to rampant urbanization and the resulting loss of functional green space both inside and outside of cities, ecosystem services are being threatened (Tallis & Kareiva, 2005). Pollination is a regulating ecosystem service that is essential for food production, plant reproduction, and life itself. Pollination can be achieved by either abiotic or biotic pollinators. Abiotic pollinators are forces such as wind and water which move pollen from one plant to another for reproduction (Methods of pollination, 2014). However, biologic pollinators such as bees, butterflies, and birds are especially sensitive to anthropocentric activities.

Pesticide application, landscaping choices, habitat loss or fragmentation, and widespread monocultural agriculture practices can all be detrimental to biotic pollination populations (Fischer, Eichfeld, Kowarik, & Buchholz, 2016). An empirically observed decline in important pollinator species has been seen in every continent, except Antarctica, it is thought to be the result from significant losses in both habitat and biodiversity (Coutts & Hahn, 2015). This decrease in pollinator populations has led to growing concern about the fate of ecosystems and agriculture (Millennium Ecosystem Assessment, 2005).

I have discovered an applicable gap regarding research on pollinators and the ways in which green infrastructure can be used to support them. Green infrastructure can provide the habitat and resources for bees, butterflies, moths, and other biologic pollinators to carry pollen from male to female plants for plant reproduction (Coutts & Hahn, 2015). Within the past decade more attention has been given to the importance of pollinators, although to date it has been almost entirely focused on the salvation of a single species at a time. The rising interest in pollinators and the increase in initiatives to address their conservation demonstrates a neocentric shift towards prioritizing all kinds of life and acknowledging that everything in the ecosystem is connected. The neotechnic

mentality is described by Geddes as the prioritization of skills direct by life towards life (Geddes, 2007[1915]). Each project benefitting pollinators is a better use of people and resources to create a place of health and wellbeing for both people and the non-human ecosystem. The increase in abundance and varied locations of pollinator corridors, discussed as case studies in this research, demonstrates that humans are beginning to place a higher value on life and the essential ecosystem services that make it possible. Whereas in a paleotechnic society pollinators were undervalued and treated as commodities, thus leading to their decline. The decline of biologic pollinators can be linked to anthropocentric activities (Winfree, Aguilar, Vázquez, LeBuhn, & Aizen, 2009).

In 2013, population counts of Monarch Butterflies reached a historic low which prompted concern from environmental advocates and action from politicians (Maeckle, 2014). That same year, the United States Department of Agriculture and the Environmental Protection Agency released a comprehensive report on the health of honey bees which stated the factors they believe to have had the greatest impact on pollinator health. These factors included exposure to pesticides and environmental toxins, poor nutrition partly due to decreased availability of high-quality and diverse forage, exposure to pests (e.g., Varroa

mites) and disease, and bee genetics resulting from selective bee breeding by pollination corporations (Pollinator Health Task Force, 2015).

In 2015, President Barack Obama released The National Strategy to Promote the Health of Honey Bees and Other Pollinators, which unveils the administration's plans for a large pollinator corridor along the route of Interstate-35 (Maeckle, 2014). This attention from the Federal Government reflects a rising interest from the American population in the welfare of pollinators. However, a large portion of this attention has focused on only two species of biologic pollinators, European honey bees (*Apis mellifera*) and monarch butterflies (*Danaus plexippus*). Much less attention has been given to native pollinators such as solitary bees, bumblebees, or butterflies, even though some research is beginning to indicate that these native pollinators are ecologically significant and do more pollination on an individual basis than the charismatic monarch butterfly and European honey bee (Potts, et al., 2010) (Garibaldi, et al., 2013) (Gashler, 2011).

Pollinators face numerous serious threats and are currently considered to be disappearing at alarming rates (Potts, et al., 2010) (Fischer, Eichfeld, Kowarik, & Buchholz, 2016) (Xerces Society, n.d.). But little research explores the use of green

infrastructure to support pollinators in this time of declining populations, likely because this is a relatively new topic of interest which began in the early 2010's. Insect pollinators are synanthropic, meaning they are able to thrive in urban habitats due to high mobility and resource requirements. Diverse populations of bees have been shown to thrive in urban landscapes through studies of native bee richness and abundance (Hall, et al., 2017). Because of the lack of research and their synanthropic characteristics, I have chosen to focus on insect pollinators for my thesis.

A new, innovative way to address the issue of urban pollination is through the implementation of pollinator corridors. Habitat connectivity is key to the conservation of any wildlife (Beier & Noss, 1998) and this is true for insect pollinators as well. Pollinator corridors create safe paths for pollinators by connecting fragmented green spaces through the planting of flowering plant species.

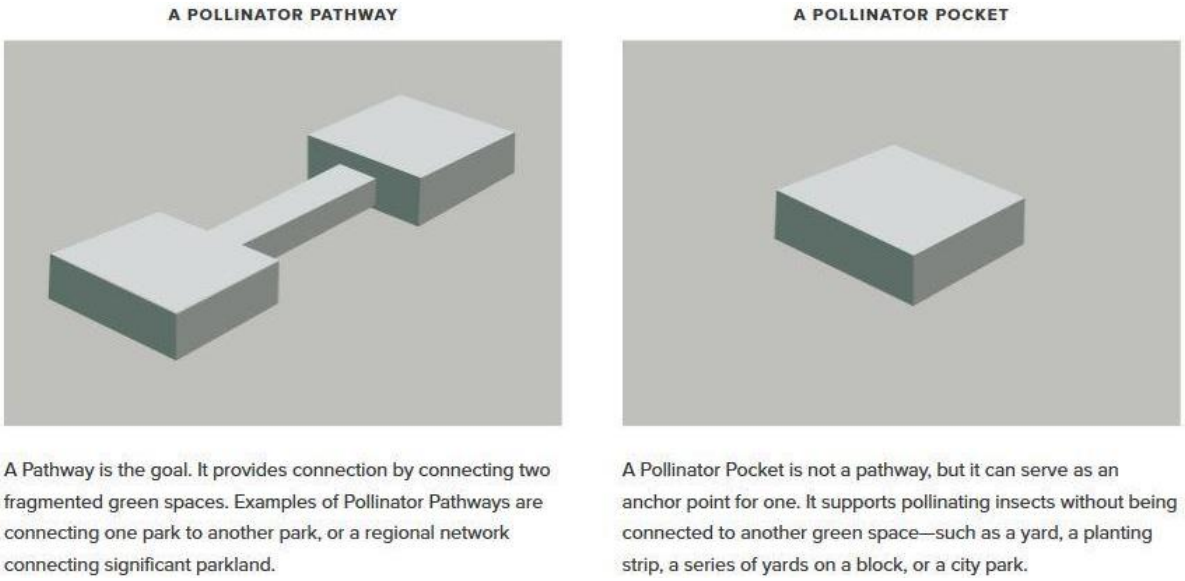


Figure 1. Diagram of pollinator pockets and corridor.

Source: http://www.pollinatorpathway.com/criteria

These plantings not only provide additional food and resources to biologic pollinators but also offer some respite from anthropocentric activities such as pesticide application and help to alleviate land fragmentation (Coutts & Hahn, 2015). Pollinators coexist well with human populations, but the lack of productive green space in urban areas can be detrimental especially during winter when food resources are scarce. Implementing pollinator corridors to connect fragmented green spaces creates more habitat and resources for pollinators which will have positive impacts on agriculture and urban ecology (Fischer, Eichfeld, Kowarik, & Buchholz, 2016).

I am interested in how green infrastructure design changes depending upon the context of the built environment and social systems. The concept of novel ecosystems, discussed by Dr. Dooling (2015), details how urban, novel systems should be handled differently than natural, less human-influenced landscapes. The goal of improving Waller Creek should not aim to restore it to conditions prior to human intervention but should try to promote a new standard of ecologic health, one that incorporates humans and the natural environment. It is not feasible to return Waller Creek to conditions prior to human settlement, as humans can never be removed from the ecosystem. We should instead seek to understand the ecology of our urban systems and strive to become better stewards of our environments. If done correctly, these novel urban ecosystems can be just as functional and healthy as pastoral ecosystems without removing human components.

Cities are great spaces for green infrastructure pilot projects because cities allow for the greatest flexibility (Ahern, Cilliers, & Niemela, 2014). Urbanized areas do not need all ecosystem services and can be supplemented with anthropocentric systems according to Andersson et al (2014). These urban, experimental projects can be designed to test innovative yet unproven solutions

with an understood risk of failure. This “safe-to-fail” framework can provide a structure to integrate science, professional practice, and stakeholder participation in experimental designs or pilot projects, of small spatial extent such that their failure would not result in major disasters or politically negative publicity (Ahern, Cilliers, & Niemela, 2014, p. 255).

Urban Planning

Andersson et al. (2014) also highlight the tendency for planning to think of green space at larger scales while neglecting the intricate complexity of urban land uses and the need for interconnected networks of small-scale green space. Many ecosystem services depend on functional complexity and do not adhere to man-made boundaries or jurisdictions. The urban fabric is a complex tapestry comprised of the built matrix of corridors interwoven through a mosaic of industrial, residential, and commercial patches interspersed with green spaces. Urban green spaces are diverse and can be classified as either formal or informal. Formal green spaces are highly managed and include parks, gardens, and recreational venues, while informal spaces are wilder and consist of overgrown lots, forgotten utility corridors, and less managed gardens. Urban ecosystems are

complex, heterogeneous systems that require a landscape ecology perspective to investigate the interrelationship between the spatial structure of cities and the ecological function (Lovell & Taylor, 2013) (Breuste, Niemela, & Snep, 2008).

While green infrastructure should be more intricate than large regional plans, truthfully both a landscape perspective and smaller, micro-plans are often needed for proper management and implementation. David Pye (1968), in his book about craftsmanship and woodworking, discusses the architectural term of diversity. "A thing well designed with intention, continually reveals new complexities of formal elements the more you inspect it (p. 62-63)." This is true of any well-designed building or woodworking project, and so too must it be true of planning. At each level of analysis, as one moves to a smaller scale, a new intricacy of a plan should make itself apparent, creating a layering of micro-plans nested within regional plans.

Colding (2007) suggests that the composition of small patches of green space or infrastructure is not as important as the composition of the adjacent green spaces. I disagree with this statement; the design and composition of green infrastructure is equally important and dependent upon its adjacencies. Habitats need to be well designed while also connected and related to other

habitats to be effective. Land uses should complement each other and form a network to support urban species diversity and abundance. From this research, I can conclude that my proposed interventions will be small-scale green infrastructure such as pollinator habitats to improve habitat connectivity through improvements along the urbanized Waller Creek. Using the multi-functionality of green infrastructure to create a healthier urban environment within the already existing urban fabric.

It is becoming increasingly apparent that planning and design need to more consciously incorporate ecosystem functionality into urban planning. Due to the relative novelty of this framework, sustainable urban planning and design will rely on emerging urban planning and design theory combined with new knowledge in design and engineering. A transdisciplinary approach, across planning professionals, scientists, urban dwellers, and engineering professionals, is necessary for the realization of this new paradigm. Adaptive designs created by transdisciplinary partnerships in experimental settings can greatly help to develop best practices to incorporate ecosystem functionality into urban planning practices (Ahern, Cilliers, & Niemela, 2014).

Civic Environmentalism/ Ecology

When intentionally designed, green infrastructure projects located in urban centers have the unique and simultaneous potential to promote ecosystem and human health. Public spaces designed for social interaction often facilitate bridging interactions between different social groups, whilst providing opportunities for local residents to participate actively in green space planning processes (Middle, et al., 2014, p. 638). According to both civic environmentalism and urban ecology literature, a thriving urban ecosystem relies upon both green and social systems. Urban green spaces, are often highly managed and heavily influenced by human intervention to the point of ecological functions being intertwined with cultural functions. Vibrant social systems are essential for the long-term success of designed landscapes. To that end, human connection to landscapes can be strengthened through the integration of diverse public preferences in landscape designs, education of people on sustainability through interactions with nature, recognition of the importance of personal and cultural connections to landscapes, and efforts to improve overall human health and wellbeing (Lovell & Taylor, 2013).

The product of my thesis will provide guidance to local communities to engage with their environment through the implementation and involvement with small-scale green infrastructure projects. Waller Creek, a landscape thoroughly intertwined with the human environment, has the best chance of being ecologically maintained if it evokes the sustained interest of people that compel the aesthetic experience (Décamps, 2001). Since the green infrastructure I recommend will be likely implemented and maintained by local stakeholders it is important for communities along the creek to be interested and to believe in the project. According to Agyeman & Angus (2003), the key to civic environmentalism is good public participation. To create strong, sustainable communities that are actively engaged with their environment the entire process needs to be open and transparent to create public buy-in and interest. The community should be involved from the beginning and have a civic desire to create change.

Civic ecology encompasses the approach of managing natural resources through the education and empowerment of communities to help people learn, organize, and act in ways to create more resilient social-ecological systems. Community greening, through civic ecology, can empower urban resilience by

supporting self-organization and creating constructive feedback loops. Civic activism builds resilience through the creation of opportunities for self-organization which empowers communities to manage their own resources. Community resilience is reinforced through positive feedback loops which support the acquisition of new skills and knowledge which integrates negotiation, reflexivity, participation, and systems thinking as strategies to incorporate ecological complexity and the diverse experiences and knowledge of multiple stakeholders in addressing management issues (Krasny & Tidball, 2009).

CHAPTER 2: STUDY METHODS

Research Design

The following chapter outlines the research questions and the methods used by this study to address them. This research provides guidance for local communities to learn how to implement well designed and manageable, pollinator-focused green infrastructure to establish a pollinator corridor along Waller Creek. All research questions were formed to gather and assemble knowledge about the installation of quality pollinator habitat. This thesis identifies existing gaps in the literature about green infrastructure regarding pollinators, explores the differences in design of green infrastructure in various contexts, and contributes to the body of knowledge about how social systems and civic environmentalism can play essential roles in the success of green infrastructure in urban ecosystems.

My research questions are as follows:

1. What pollinator-focused green infrastructure designs are most likely to benefit the urban ecology of Waller Creek, an urban creek in Austin, TX given its unique social and environmental characteristics?

2. How will pollinator-focused green infrastructure design and maintenance strategies change depending on the adjacent urban context and user requirements?
3. What are the most common obstacles, perceptions, and motivating factors when implementing pollinator-focused green infrastructure?

These questions inform the direction of my research. Because green infrastructure is context dependent, I hypothesize that designs for green infrastructure interventions and maintenance strategies will change depending on the surrounding built environment. Additionally, since successful maintenance is key to the longevity of living projects, I hypothesize that civic environmentalism and social systems are integral components of green infrastructure plans. Maintenance is often an afterthought when designing green infrastructure, but without long-term, proper maintenance projects will not last. This research hopes to produce a useful guide for local communities of Waller Creek who wish to implement their own pollinator infrastructure. This guide outlines best practices for pollinator garden, helpful resources, identifies some common mistakes, and highlights some motivating factors.

Key Terms

The table below defines key terms used during this research.

Table 1. Key terms and definitions.

Term	Definition
Green Infrastructure	"Natural, semi-natural and artificial networks of multifunctional ecological systems within, around and between urban areas, at all spatial scales." (Tzoulas & James, 2010).
Ecosystem Services	Ecosystem services are the benefits and services provided by nature that facilitate life. These services can be broadly divided into four categories: provisioning services such as food and water; regulating services such as flood regulation and pollination; supporting services such as soil formation and photosynthesis; and cultural services such as recreational and spiritual benefits. (Millennium Ecosystem Assessment, 2005)
Pollination	A regulating ecosystem service that allows the transfer of pollen from one plant to another to for allow fertilization.
Pollinator Corridor	A safe path for pollinators made by connecting fragmented green spaces through the planting of flowering plant species.
Civic Environmentalism	"Promoting social cohesion and empowerment, ecosystem health, and the development of an environmental ethos among community members." (Lovell & Taylor, 2013)
Multifunctionality	"Multiple ecological, social, and economic functions shall be explicitly considered instead of being a product of chance." (Hansen & Pauleit, 2014)
Social Systems	A network of interrelated people, groups of people, and entities that share common interest or work together for a common goal.

Methods

Multiple methods are used to collect and interpret data for this research to answer the three research questions. Case studies have been selected and analyzed for applicable green infrastructure strategies and examples of civic environmentalism. Interviews have been conducted with professionals in fields related to pollinators, community engagement, or green infrastructure. Surveys were distributed to stakeholders invested in the prosperity of Northern Waller Creek. And finally, basic design examples have been created to provide visual guidance and highlight important tips or attributes that will help ensure the success of small scale pollinator-focused green infrastructure projects.

Green infrastructure projects that specifically target pollinators are reviewed for applicable lessons. Ultimately, the two projects I chose to focus on were selected due to their location in an urban core, use of underutilized space, efforts to create cohesive pollinator corridors, and their ability to organize local communities for support, installation, and maintenance. These projects are then analyzed for applicable strategies and lessons to this research. However, due to the relative novelty of these types of projects, both case studies began within in past ten years and are still unfinished. Thus, there are very few lessons regarding

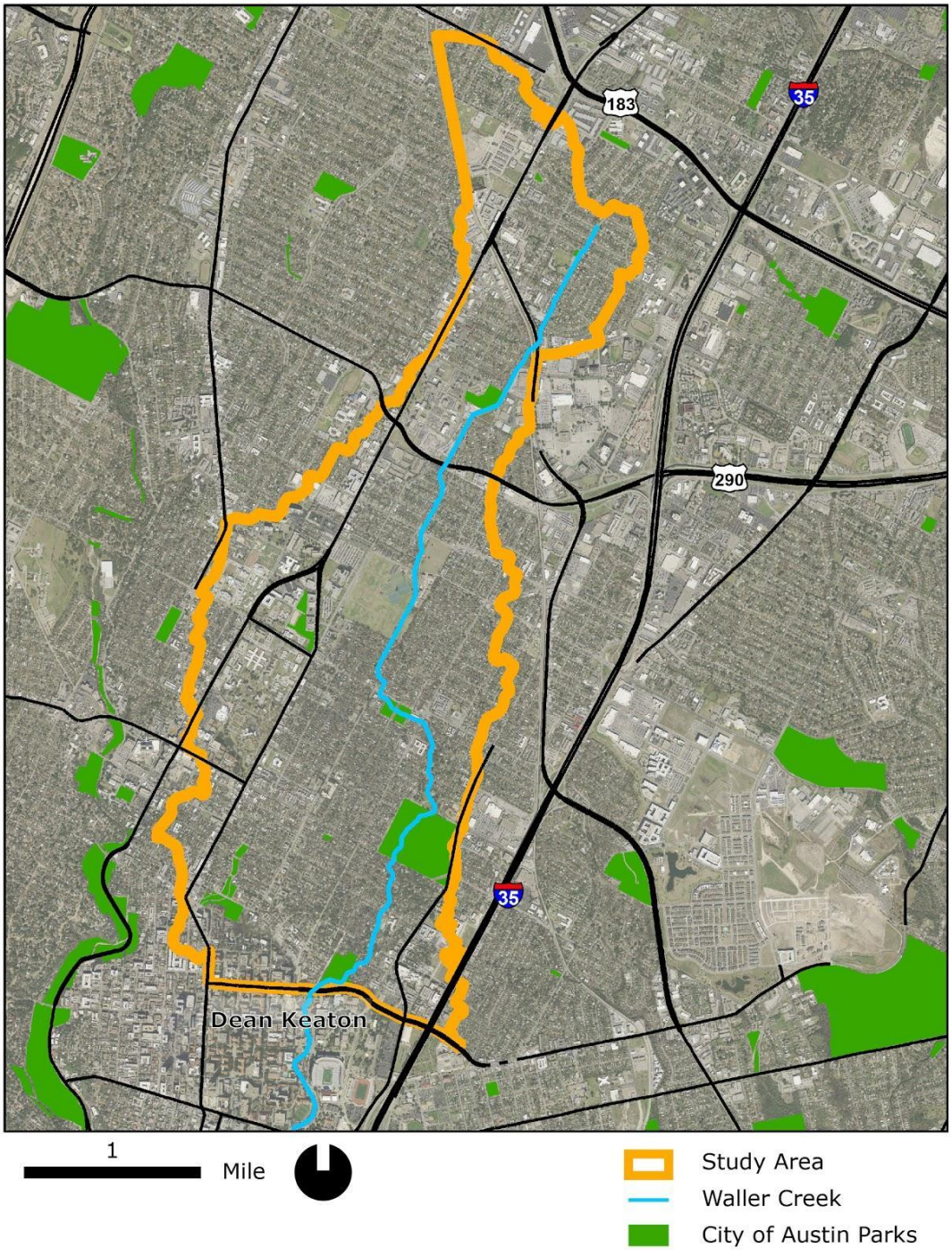
long-term maintenance strategies that can be studied. The founders of both projects were interviewed as part of both the case study analysis and the professional round of interviews.

I interviewed nine professionals working in fields related to either landscaping/ecology, pollinators, or community engagement. The professionals I chose to interview were selected through snowball sampling, or chain-sampling, where each interviewee recommended a person or persons for me to contact for an interview. This method allowed me to connect with local experts in their fields to ensure that each interview would produce valuable, accurate information. However, this sampling method can be subject to bias. Interestingly, every professional recommended for me to interview for this thesis happened to be female. It is unclear whether this is due to an abundance of women in these fields or due to a well-connected community of helpful women interested in pollinators and research. These professional interviews formed the types of questions used in my stakeholder survey. Questions for each interview changed due to the variations between each interview participant's backgrounds. Interviews consisted of approximately seven questions which followed similar themes but differed

based on participant background; generic versions of these questions will be included in the appendix.

After the professional interviews, surveys were distributed in two rounds. The target audience for the surveys was defined as anyone living in or interested in the welfare of the study area. The study area was defined as the northernmost section of the Waller Creek Watershed (seen on the map below), spanning from edge of The University of Texas Campus to the creek headwaters just south of highway 183. The entire Waller Creek watershed stretches from highway 183 down to Lady Bird Lake, generally between Lamar Blvd and Interstate 35. My study area covers only half of the entire Waller Creek watershed.

Map 1. Thesis Study Area: Northern Waller Creek Watershed. Created by Nathlie Booth.



A total of thirty-six surveys were collected during the two rounds of distribution. The first round of surveys was distributed at a meeting for the Hyde Park Neighborhood Association, Hyde Park is a historic neighborhood located in the heart of the study area. Eleven people responded to the survey at the meeting, however ten out of the eleven were homeowners. Based from the responses from the first round of local communities, I determined there was significant confusion regarding the questions. Many participants gave superficial answers which did not yield any productive insight for this study. For example, when asked if participants were familiar with the ecological significance of pollinators, all responses said simply "yes." At this point during the survey I had expected to engage each person in a conversation about the decline of pollinators and the consequences on urban ecosystems if pollinator populations continue decline at the current rates. However, due to time constraints, I was unable to engage with each participant. Survey questions were revised, complicated questions about participant's knowledge of pollinator importance we removed, and clear instructions were given on how to respond to questions. Both sets of survey questions will be included in the appendix.

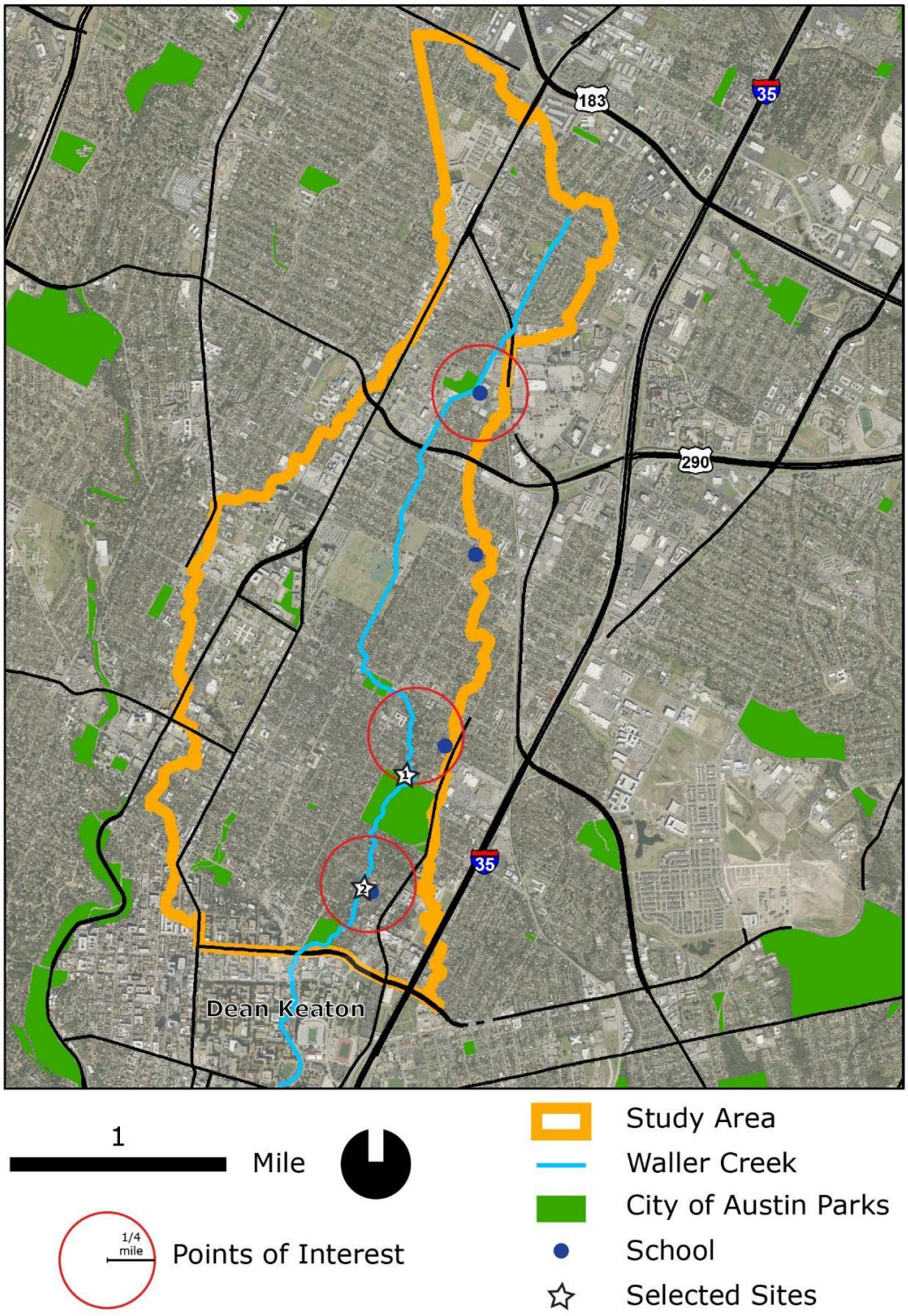
The second round of surveys was distributed at an "It's My Park Day" event at Shipe Park. It's My Park Day is a city-wide, volunteer event to maintain parks and green belts which takes place twice a year. Shipe Park, a small neighborhood park, is located within the Hyde Park neighborhood and adjacent to Waller Creek. Twenty-four surveys were collected during this event. This time homeowners comprised less than half of the sample. One additional survey was collected from a City of Austin employee who lives near the study area and is invested in the creek's welfare.

Finally, two site designs demonstrate the variations between green infrastructure strategies in different contexts. These are theoretical designs that are not currently planned to be implemented. Sites were selected based on the following criteria: location within 1/4 mile of Waller Creek, a lack of existing pollinator-focused programming onsite, and proximity to an existing green space. Typology of the adjacent built environment was also taken into consideration; the sites highlight different characteristics which result in different designs and maintenance plans.

Using GIS, points of interest were identified on the map below if a school and green space are located within a 1⁄4 mile radius from Waller Creek. Proximity

to a school is an important factor because I wanted to explore the maintenance strategies of schools due to the large educational component and summer vacancy. Areas between two or more green spaces are preferable to help create cohesive pollinator corridors along the creek. All possible points of interest are circled in red; the final two sites are highlighted with white stars on the following map. Each site reflects a different built environment requiring different green infrastructure designs and maintenance strategies. The first site is a vacant lot planned to become a hotel, a portion of the lot would be redeveloped into a neighborhood pocket park. And the second is part of an elementary school yard which would be redeveloped into educational and interactive pollinator habitat.

Map 2. Points of Interest within the Study Area. Created by Nathlie Booth.



In summation, the research questions will be addressed through the analysis of case studies involving successful applications of green infrastructure and community engagement, the valued opinions of both pollinator experts as well as communities involved with Waller Creek, and design examples of green infrastructure based off the research findings and context. Using a primarily constructivist research paradigm this thesis identifies existing gaps in the literature about green infrastructures possible applications for pollinators, explores the differences between green infrastructure design in various contexts, and contributes to the body of knowledge about how social systems and civic environmentalism can play essential roles in the success of green infrastructure in urban ecosystems.

CHAPTER 3: FINDINGS

The following chapter will outline the findings resulting from the data collection methods used for this study. The first section details the findings from the case study analysis of two examples of pollinator corridors in urban centers. The second section discusses the interviews with professionals working in fields related to pollinators or landscape design in Austin. The third section outlines the results from the stakeholder surveys of local communities within the study area. And the final section discusses two example site designs of pollinator-focused green infrastructure that could be implemented by stakeholders. Together, all these findings combined with earlier research help to create a short handout which can provide guidance for those who wish to implement pollinator-focused green infrastructure in Austin, Texas.

Case Studies

Case studies of similar projects were examined for successful applications of pollinator-focused green infrastructure and successful maintenance of that infrastructure. Two of those case studies were selected for further examination:

The Pollinator Pathway in Seattle, Washington and The Grey Lynn Pollinator Path in Auckland, New Zealand. Each case study was selected because it was implemented in an urban location, applied pollinator-focused green infrastructure, created a pollinator corridor, and relied on local communities for installation and maintenance. Both projects are composed of small scale interventions that create a larger pollinator corridor to promote habitat connectivity. Both target primarily insect pollinators with plantings and artificial habitat construction and both have engaged local communities to implement and maintain the project while spreading awareness about the importance of pollinators. Although, due to the relative novelty of these types of initiatives, neither project is old enough to study the lasting strategies for maintenance.

POLLINATOR PATHWAY (SEATTLE, WASHINGTON)

The Pollinator Pathway is an interdisciplinary design initiative, which began with the pilot project titled "The Pollinator Pathway" and was founded by Sarah Bergmann in late 2007. Bergmann designed the pilot project as a response to the way mankind has irrevocably impacted landscapes and ecological systems.

The Pollinator Pathway is a public design project as well as a book and museum piece which tells a broader story about nature and connectivity.

Although the project focuses on pollinators, The Pollinator Pathway is not a project to save the bees. The disappearance of the honey bees is only one symptom of a greater problem, Bergmann takes issue with the way humanity treats the environment as either a commodity or an afterthought. The goal of the Pollinator Pathway initiative is to reimagine our relationship with nature to create a healthier global ecosystem through connectivity and increased biodiversity. Bergman argues that we should not think of humans or cities as separate from nature. Nature no longer exists solely outside of cities; humans and cities are intricately interwoven as part of natural systems. The Pollinator Pathway's pilot project is a design proposal to redesign and reimagine the narrative between the humankind, nature, and culture in the Anthropocene (How it Started, 2018).

The Project

The Pilot Project, located in Seattle, Washington, is a one-mile long stretch of twelve-foot-wide green spaces connecting two parks to form a pollinator corridor. The pathway is made of about 20 pollinator-friendly gardens built in the city-owned right-of-way planting strips in front of residential homes. Each garden

is funded, researched, and designed individually. The gardens form a pollinator corridor which connects Nora's Woods with the Seattle University Campus. Nora's Woods is a small neighborhood pocket park about the size of a single residential lot located in Seattle's Madrona neighborhood. The park was founded by a woman named Nora and has been preserved since the 1980's. The woods are maintained and cared for by the neighborhood and house many native plant species. Seattle University has a long history of sustainable landscaping practices and multiple pollinator friendly gardens making it an ideal spot to connect (The Pilot: Seattle's First Pollinator Pathway, 2018).

Figure 2. Before and After Pollinator Pathway.

Source: http://kuow.org/post/seattle-woman-builds-pathways-bees-birds-and-other-pollinators

Both end points were chosen by Bergmann due to their pesticide free maintenance as well as proximity to each other and relative importance to local pollinator species. The sites are connected by a stretch of detached single-family houses along Columbia Street; this is the location of the Pollinator Pathway project. Bergmann spent many years convincing homeowners to tear out the grassy planting strip in front of their house and plant flowering native species that benefit pollinators. According to the website, the Pollinator Pathway assists with garden design and implementation however homeowners are responsible for maintenance.

For 6 years the project was monitored by Erin Sullivan, an entomologist working with the Pollinator Pathway, to discover the species that visit the gardens and which plants they prefer to inform future designs (Connecting Two Landscapes: Nora's Woods to Seattle University's campus, 2018). Weekly surveys quantified the types and abundance of pollinators visiting the project. A clear trend of increasing biodiversity was observed over the 6 years of study with the number of pollinators visiting the site each week increasing from about zero visits, when there was only turf grass, to approximately one thousand after the project had been established for six years (Bergmann, 2017).

Although the pilot project began ten years ago, today it is only approximately one-third complete. Bergmann stated in our 2017 interview that the project has remained incomplete due to personal circumstances, logistic complications, and a general lack of understanding from the public and press (Bergmann, 2017). Bergmann wanted the project to be a catalyst for people to take action and create their own projects to establish synergy between people and the environment by making urban spaces support connectivity, density, and increased biodiversity. Instead the public became fixated on this short-term goal of saving the honey bees. People misunderstood the Pollinator Pathway, which is a micro-project of a larger design initiative to create symbiosis between cities and natural landscapes, as the complete scope of an initiative to save the honey bees.

Results and Lessons

The pilot project in Seattle, Washington, was always meant to be a design exercise for Bergmann, to develop a way of thinking about the larger questions of systems thinking. Today the Pathway is a global call to action or a Design Challenge to the Planet (What is the Pollinator Pathway?, 2018). Bergmann grew frustrated with people's singular fixation on saving the honey bee. In our interview, she likened the honey bee to dairy cattle. This same comparison

between honey bee and cattle was also made by a biologist studying bees in Austin. This analogy means that the honey bee is by no means the only or most important insect species for pollination, but it receives all the attention because of the product it produces for humans and its agricultural services (Bergmann, 2017).

Bergmann wants more attention to be focused on the way humans fragment landscape and create these ecological problems for all pollinators instead of retroactively trying to save a single species because we place value on it. As she put it in an interview for the podcast "In Defense of Plants", adding more cows to grasslands will not help the grasslands, just like adding more honey bees will not boost ecology or improve the environment (Candeias, November 5, 2017). Agricultural monocultures, low biodiversity on farms, and an over-reliance on honey bees for pollination created the problem of disappearing honey bees (Fischer, Eichfeld, Kowarik, & Buchholz, 2016). Creating counter systems of biodiversity to combat monocultures and urban sprawl will improve ecosystem health.

Bergmann's pathway is one of the first successful examples of pollinator-focused green infrastructure and still inspires urban ecologists today. This case

study was chosen as an example for this study because it used underutilized urban space, created a pollinator corridor, and relied on local communities for installation and maintenance. The pilot project also places importance on native pollinator species and habitat connectivity to boost ecological coherence. All of which are goals for the eventual implementation of this thesis. The framework Sarah Bergmann developed which places emphasis on the prioritization of increasing biodiversity and landscape connectivity without contributing to urban sprawl has been adopted in this research.

From this case study several lessons can be learned. First, green infrastructure that supports pollinators should be used effectively in underutilized spaces so as not to contribute to urban sprawl. The practice of adding random plants to the sides of roads or to outdoor spaces of large developments serves only to decorate the sprawl of cities. While on an individual scale adding plants to sprawling infrastructure is not problematic, but when replicated across the country, the result is more roads and large developments decorated by plants without prioritizing ecosystem connectivity and functionality from the beginning. Landscape connectivity and ecosystem functionality should be incorporated early in designs of new developments to create ecologically beneficial spaces.

Bergmann uses the term “ecological judo” or the process of combating sprawl by using underutilized, non-developable spaces such as transmission lines or yards to connect landscapes and promote biodiversity within the city (Candeias, November 5, 2017). The goal is to prioritize ecosystem functionality and incorporate well thought out plantings into the design of the site instead of adding random landscaping after the building or site is mostly designed.

The second lesson is the recurring problem of long-term successful maintenance. Many green infrastructure projects encounter problems with maintenance because people tend to think in periods of five or ten years instead of fifty. Truly long-term maintenance, that does not plan to be rebuilt after thirty or fifty years, requires involvement at all levels. Usually, as demonstrated by these case studies, public buy-in and enthusiasm are required for most projects to get off the ground. Through civic environmentalism and engagement, the public can help to maintain projects for some time but not usually for the long-term management that green infrastructure requires. For that, institutional support is necessary.

Government or non-profits usually have the resources and scope to be able to consistently maintain projects for the long-term. In these partnerships,

the ideal balance is for the majority of project maintenance to fall upon these institutional groups, with volunteers only providing occasional assistance. This type of partnership can be seen in the way that government institutions maintain parks, creeks, and roads, yet volunteers still find it necessary to organize clean ups and "adopt" sections to pick up the slack. However, even with support across institutions and community groups, these living projects can be difficult to maintain long-term. Perhaps static long-term maintenance is not required for every green infrastructure project. Landscape ecology teaches us that landscapes and environments change over time, perhaps the management of these green infrastructure projects should be reevaluated as landscapes and social systems change.

The third lesson is the importance of the priorities of our civilization. Human values dictate our physical world. The prevailing culture of North America dictates that a neat, orderly landscape is a sign of neighborliness, hard work, and community pride. Yet these orderly landscapes rarely do much, if anything, to enhance ecosystem function (Nassauer, 1995). We as a society need to value ecosystem function and prioritize a holistic approach to creating symbiosis between cities and nature. Robert Young discusses the need for a shift towards a

biocentric civilization, where life is prioritized over profits and commodities, which means shifting the Anthropocene away from a human dominated system to an ecosystem dominated system, recognizing that humans and nature are part of the same global ecosystem (Young, 2017). In some ways, these pollinator corridor projects could be the first sign of this shift in global prioritizations.

GREY LYNN POLLINATOR PATH (AUCKLAND, NEW ZEALAND)

Pollinator Paths is a new movement that aims to connect Auckland's major parks through a pollinator corridor to create an ecosystem network that restores the ecological balance in Auckland. The founder, Andrea Reid, started the movement in 2014 as a part of her university thesis. Reid now works with the Waitemata Local Board, Auckland Council, local communities, Grey Lynn 2030, Grey Lynn Residents Association, AECOM and Kai Auckland to create a series of prototype parks to be installed throughout the city starting in Hakanoa Reserve Grey Lynn in October 2016. The goal of the movement is to create safe passageways for native pollinators to venture into urban areas and promote local, urban agriculture (Our Story, 2017). Pollinator Paths does an excellent job of

utilizing underused spaces in urban areas, each pollinator park is being built on either empty lots or right-of-way buffers.

The Project

The first pollinator corridor from Pollinator Paths is the currently underway, Grey Lynn Pollinator Path. In 2016, Auckland Transport and the Waitemata Local Board began construction on a walking and cycling path that will connect Cox's Bay Reserve and Grey Lynn Park. Cox's Bay Reserve is a large green space and sports complex located in the center of Auckland along Cox's Bay. Grey Lynn Park is another large green space, with significant local importance, located southeast of Cox's Bay Reserve.

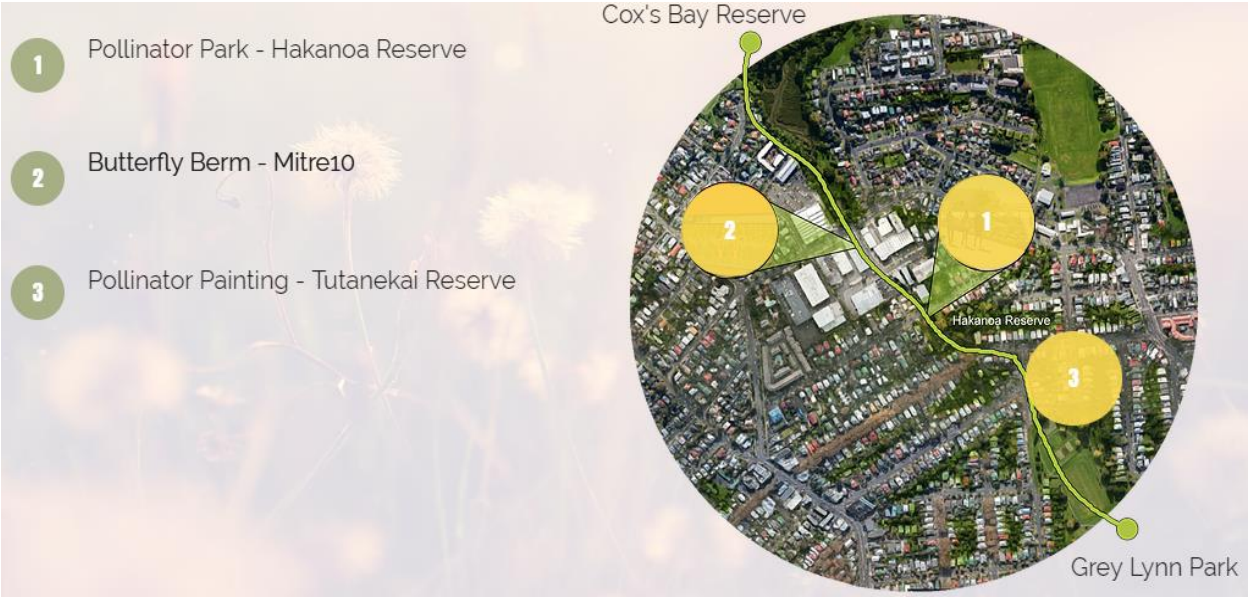


Figure 3. The Grey Lynn Pollinator Path.

Source: https://www.pollinatorpaths.com/grey-lynn-pollinator-path

The proposed pollinator corridor is a little less than a mile long and is being completed in segments as they become approved by Auckland Transport, Auckland Council, Waitemata Local Board, other local boards, and most importantly as Reid secures funding. The corridor will link the two large green spaces through several small pocket parks located on the new cycling path while encouraging pollinators to populate urban areas to boost the urban ecology of Auckland. The walking and cycling path will be incorporated with pollinator-focused programming to create a synergy between people and the environment.

To date three installations have been designed and approved for the Grey Lynn Path. These projects are the Pollinator Park, the Mitre10 Butterfly Berm, and the Pollinator Painting. They will act as the anchors of the pollinator corridor, with some small plantings dispersed along the rest of the path to create a coherent corridor. The first installation, completed in October 2016, is the Pollinator Park. The park is located halfway between Cox's Bay Reserve and Grey Lynn Park in the Hakanoa Reserve along the proposed walking and cycling Path. It is a small triangular plot of land filled with native plants to attract local pollinators as well as artificial habitat. Pollinator Paths partnered with local residents and volunteers as well as Auckland Enviroschools to install the park (Our First Path!, 2017). Enviroschools is a network of early childhood centers and local communities who want to teach children how to make a positive impact on the environment (Enviroschools reflect on Change, n.d.).

Figure 4. Pollinator Park Rendering.

Source: https://www.pollinatorpaths.com/grey-lynn-pollinator-path

The Pollinator Park contains several key features to support and provide resources for populations of native pollinators in the urban core of Auckland. These features include artificial habitat for specific types of pollinators, several native plants, and signage to educate the public on pollinators and the project. This project seamlessly incorporates local communities into the park to integrate people with pollinators. For example, a cascading masonry wall was built and filled by local children with a range of different materials that target different

native pollinators. They have also installed a little library box filled with books for the community onsite. Funding for this project was provided by the Waitemata Local Board and was completed in partnership with Gecko NZ Trust (Our Supporters, 2017).

The second installation entitled the Mitre10 Butterfly Berm will be located north of the Pollinator Park along the proposed corridor. In our 2018 interview, Reid said she has recently secured a funding package that will support the installation of this project and the final installation. The Mitre10 Butterfly Berm is planned to be installed in April 2018 (Reid, 2018). It will essentially be a living wall and adjacent planting strip attached to Mitre10, which is a home improvement store in Auckland. The Butterfly Berm, as the name implies, will focus on attracting and providing for native butterfly populations. The current site is a grass berm that varies in width and spans approximately 400 feet along one wall of Mitre10. The design will include butterfly feeders as well as a range of plants specially designed for each type of butterfly. The installation will provide habitat for monarch, copper, blue and tussock butterflies. This project is supported by The Moths and Butterflies of New Zealand Trust (Our Supporters, 2017).

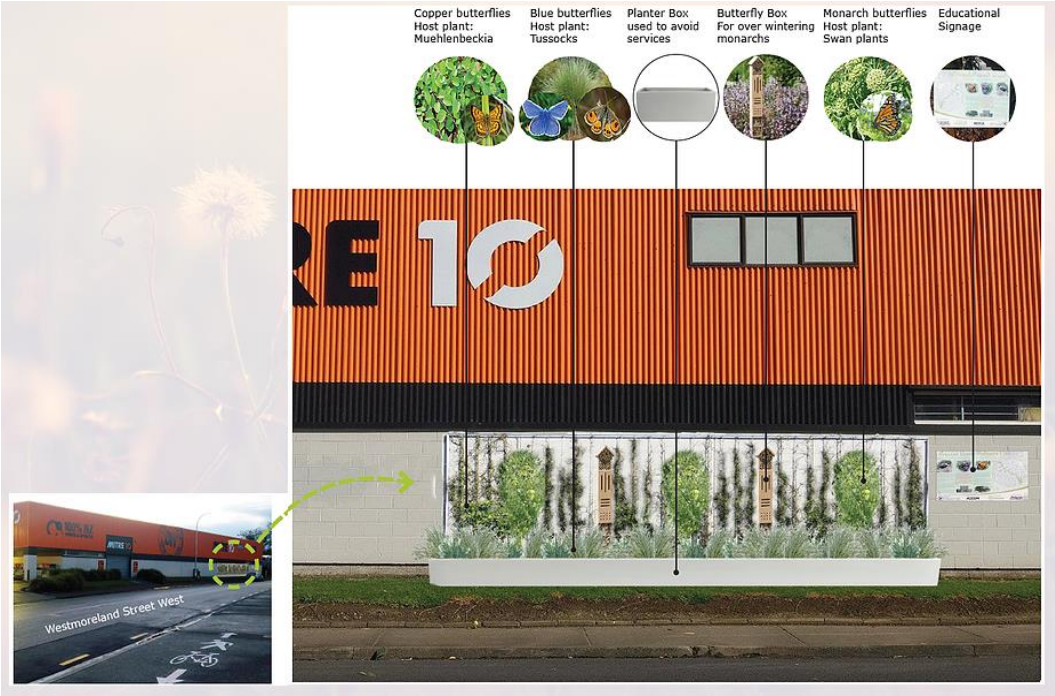


Figure 5. Mitre10 Butterfly Berm Rendering.

Source: https://www.pollinatorpaths.com/grey-lynn-pollinator-path

The third installation is called the Pollinator Painting and will be located south of the Pollinator Park along the Grey Lynn Pollinator Path. The site is currently a small, grassy lot at the intersection of two roads and is owned by Auckland Transport. Grey Lynn Park is located directly across the street from this site, making The Pollinator Painting the connection between the Pollinator Path and Grey Lynn Park. This installation provides crucial host plant for Auckland's native bee populations. In our 2018 interview, Reid stated that in New Zealand

there is an overabundance of non-native pollinators that outcompete the native pollinators for resources. So, in response to this native pollinator crisis Reid incorporates plant species that specifically target native pollinators into her parks (Reid, 2018). Native, flowering plants will be "painted" over the grassy space to create strips of color inspired by work done by For the Love of Bees, which is a City Bee Collaboration, working to educate the public about the threats to New Zealand's native bee populations. The plants will be sown in such a way that will not break the ground and disrupt underground utility services as this was a concern from the city. This project is supported by For the Love of Bees (Our Supporters, 2017).

Figure 6. The Pollinator Painting.

Source: https://www.pollinatorpaths.com/grey-lynn-pollinator-path

In each installation long the Grey Lynn Pollinator Path, educational signage is crucial to provide information on the pollination, plants, and the importance of the project. Each installation is entirely funded by grant funding, local donations, and volunteer work all secured by Andrea Reid (Our First Path!, 2017). To date she has secured funding for the three anchor projects along the corridor but still needs additional funding for the dispersed plantings along the corridor. The

project relies heavily on community engagement for the implementation and maintenance of each project. She expects that the Grey Lynn Path will be completed within a year or two.

Results and Lessons

The Grey Lynn Pollinator Path project differs from the Pollinator Pathway and my thesis in that it specifically provides resources for non-insect pollinators such as lizards and birds. Not to say that either mine or Sarah Bergmann's project excludes or wants to exclude these pollinators. The Pollinator Park in Auckland just makes the connections and desires for these other pollinators more explicit and intentional. Had I more time, I would have liked to incorporate resources and designs to provide for birds and lizards as well. Instead I will rely on the multi-functional overlap of natural systems to unintentionally provide additional habitat and resources.

There are two very important lessons I can learn from The Grey Lynn Pollinator Path regarding maintenance and community engagement. The first is that community engagement must be done properly for it to be useful. Pollinator Paths met very little resistance from local communities because Andrea Reid made sure to educate people from the very beginning. She posted flyers and

educational signs making sure people understood the importance of her project. Local groups were also involved in the installation of the projects, which helped to create a sense of ownership between communities and these parks (Reid, 2018).

Second, maintenance cannot be accomplished by one group alone. For successful green infrastructure, long-term maintenance is required. And for long-term maintenance, transdisciplinary cooperation is needed, in this case cooperation between local communities and city government. Like most green infrastructure projects, The Grey Lynn Pollinator Path struggles with maintenance. Since Pollinator Paths is solely run and managed by Reid, it is not feasible for her to maintain the whole path over the course of its life. There is still an ongoing debate in Auckland over who should be responsible to maintain the parks. Andrea Reid is trying to make the case to the local board that it would be cheaper and more environmentally beneficial for the city to maintain the parks as opposed to paving over the sites or just planting grass, which is the alternative if the project is unsuccessful. She has designed the parks to eventually be self or low-maintenance by using ample ground covers to smother weeds and spacing

plants close together (Reid, 2018). But it is still important to maintain the park properly as the plants become established.

Currently the project is maintained by volunteers who are recruited by Pollinator Paths. This is obviously not sustainable, Reid does this work out of dedication to her project, but it is not her full-time job. And although people were excited about the installation of the pollinator park, few are as excited about regular maintenance. She has had to market maintenance as anniversary events and celebrations with speakers and music and a little maintenance snuck in. Even when the volunteers are drummed up, they still need to be monitored and organized or they tend to over maintain or pull the wrong plants (Reid, 2018). Although civic environmentalism is great for project installation and occasional maintenance, there must be other systems in place to pick up the slack. Green infrastructure cannot always rely on volunteers to care for parks every time maintenance is needed throughout the parks life.

But there are also issues with the city maintaining the projects as well. Mainly, city maintenance staff tend to have a protocol in place which usually involves spraying pesticide and/or mowing, neither of which can happen in these pollinator parks. These protocols are often difficult to change because they

require a complete retraining of staff, approval of new techniques, and often more effort than simply spraying pesticide or mowing grass. But the city needs to be involved in the proper care of these parks for them to last. The city is legally responsible for the park; if Pollinator Paths stops maintaining the project for some reason it's the city's responsibility to step in and maintain this infrastructure. Luckily, Andrea Reid is dedicated and would like to see the parks succeed and not be paved over to avoid maintenance (Reid, 2018).

Although there is never a one-size-fits-all solution, it seems from the literature review and case studies that a combination of community and city efforts is required for the successful maintenance of these pollinator corridors. Local communities are great for help installing projects and even for the occasional maintenance but a larger, more organized group such as the city is needed for consistent, comprehensive maintenance. But in each case proper maintenance needs to be used for these pollinator-focused green infrastructure projects. Volunteers and city staff need to be taught which plants should be pulled versus which are desired, how to care for these plants organically, and perceptions need to be changed as well.

Many people have the perception that a healthy ecosystem is neat and highly managed when in fact overgrowth can be ecologically beneficial. Within the City of Austin Watershed Protection Department there is a program called, "Grow Zones." The program establishes areas along Austin creeks which are not to be mowed, allowing for plants to grow naturally to create a riparian buffer. These zones are more beneficial for creek health as they resemble a natural riparian system which allows for passive filtration and wildlife habitat. However, the city receives frequent complaints about the "messy" or "overgrown" aesthetic of the grow zones. Without the perception of human intention landscapes are often mistaken for neglected or land awaiting development. The fact that apparent naturalness can lead to such perceptual mistakes about ecological function underscores the power of the cultural concept of naturalness (Nassauer, 1995). There is often a disconnection between people's perceptions of healthy ecosystems and healthy, wilder ecosystems (Coyne, 2015).

Interviews and Surveys

This section details the findings resulting from professional interviews and surveys of Waller Creek stakeholders. Interviews were first conducted with

professionals and then followed by two round of surveys targeting people invested in the welfare of the study area. These interviews and surveys were conducted over the course of four months. Due to differences in professions and work experience, interview questions varied between each interviewee. Each interview consisted of seven questions, which all covered similar topics but varied slightly. Survey questions for community stakeholders changed once to become more specific due to participant confusion. Both versions of the survey are in the appendix as well as generic iterations of the seven questions asked during interviews.

PROFESSIONAL INTERVIEWS

Interviews were first conducted with professionals working in fields related to pollinators, landscape ecology, or community engagement. These interviews informed the example site designs for this study as well as the survey questions for stakeholders in the study area. In total 9 professionals were interviewed over the course of four months. Participants were found using snowball sampling, thereby ensuring that each interviewee was recommended by a group of their peers and would yield a productive discussion concerning pollinators, urban

ecology, landscape design, or community engagement. Due to the inherent nature of snowball sampling, there is some bias in the participant selection. For example, every professional recommended to me happened to be female; meaning there is either an abundance of women in these fields or more likely I tapped into a network of well-connected, helpful women interested in pollinators and research.

Interviews were conducted either in person, over the phone, or on Skype and each lasted between thirty minutes to one hour. Each interview consisted of approximately seven questions which changed depending on the interviewee's background and work experience, although each participant was generally asked for their opinions on designing quality pollinator-focused green infrastructure and if they had any advice regarding citizen participation or who should be involved in the stewardship of Waller Creek. All but two of the participants were based locally in Austin. The two professionals not based in Austin were the founders of the case studies and since those interviews were discussed at length in the previous section, this section will focus mainly on the seven local interviews.

The place of work for each professional interviewee is outlined in the table below, respondents will be identified by their place of work to protect their identity. It is worth noting that two employees were interviewed from The Lady Bird Johnson Wildflower Center. The primary focus of these local interviews was to ascertain knowledge about good pollinator habitat design for northern Austin, successful maintenance strategies, how to best engage local communities, and to help identify native pollinators and plants within the study area.

Table 2. Workplaces of Professional Interviewees.

Entity	Description
The Lady Bird Johnson Wildflower Center	Texas botanical garden and arboretum, home of sustainable, native plant gardens and education, conservation, research and consulting programs (https://www.wildflower.org/about).
The Jha Lab	Investigates ecological and evolutionary processes from genes to landscapes, to quantify global change impacts on plant-animal interactions, movement ecology, and the provisioning of ecosystem services (https://w3.biosci.utexas.edu/jha/).
The Nature Conservancy	Non-profit conservation organization working internationally to protect ecologically important land and water (https://www.nature.org/about-us/index.htm?intc=nature.tnav.about).
Sustainable Food Center	Austin based non-profit organization working to cultivate a healthy community by strengthening the local food system and improving access to nutritious, affordable food (https://sustainablefoodcenter.org/about/about-sfc).
COA Parks and Recreation Department	City of Austin department in charge of all public parks and recreational facilities (http://www.austintexas.gov/department/parks-and-recreation).
COA Watershed Protection Department	City of Austin department in charge of all watershed related infrastructure, conservation, and planning (https://www.austintexas.gov/department/watershed-protection).

Pollinator-focused Green Infrastructure Design

Regarding the most important factors when designing pollinator habitat or pollinator gardens, participants gave several guidelines for designing quality

pollinator-focused green infrastructure within Austin. These include planning for biodiversity, designing for the entire lifespan of a pollinator, important physical parameters of the designs, targeting specific pollinator species, understanding user's tolerance for "messy" landscapes, and providing year-round basic necessities for pollinators.

Nearly every participant said good pollinator habitat needs to be designed for both high plant and pollinator biodiversity and to provide essential resources for every stage of the target pollinator's life. Good quality pollinator-focused green infrastructure cannot provide only food for adults or only host plants for eggs. Habitat needs to be designed to provide all basic necessities such as food, water, nesting, and shelter as well as to provide for all stages of a pollinators life, not just larval or adult stages (Wildflower Center employee, November 1, 2017; Jha Lab employee, November 27, 2017; Wildflower Center employee, November 7, 2017). The City of Austin says providing wildlife habitat is as easy as 1, 2, 3, 4! 1. Provide native plants that produce ample, year-round food for your target species. 2. A reliable water source is key for all wildlife, including pollinators. 3. Be sure to provide safe places for wildlife to hide from predators and to shelter from the weather. 4. Nesting is important for the continued survival of a species,

provide nesting boxes or places for pollinators to raise their young (Grow Green, n.d.).

To make the design of each garden easier and more manageable, one participant suggested choosing a specific number of pollinators to target with plantings. This number will depend on the physical size of each project, but she suggested around five target species for each site to ensure for biodiversity. On the plant side of diversity, a minimum of nine plant species were suggested for each project but obviously the larger the site, the more biodiversity should be incorporated (Wildflower Center employee, November 1, 2017). A biologist who studies pollinators also mentioned that plants should be selected from a variety of plant families to ensure sufficient dietary variation for pollinators (Jha Lab employee, November 27, 2017). As mentioned earlier, water sources are equally as important as food resources for pollinators. Butterflies specifically need shallow puddles of water formed on rocks to obtain essential minerals leached from the rocks by the water (COA Parks and Recreation Department, January 19, 2018).

Several physical parameters for pollinator habitat were given as well. Soil quality on site will determine the plant species able to grow but limiting the

amount of soil amendments will also keep costs for each project lower (Wildflower Center employee, November 7, 2017). The City of Austin recommends amending the soil on site with two to three inches of compost or a mix of 25% compost, 65% loam, and 10% sand (Wildlife Habitat Design, n.d.). Be careful not to over fertilize the site, as over fertilization can also create water quality problems in nearby bodies of water. Since all of these sites are located along Waller Creek, fertilization should be kept to a minimum and chemical fertilizers should be avoided.

It was mentioned by professionals as well as surveyed residents of local communities that gardening in Texas can be difficult due to the heat, soil conditions, and fluctuation between drought and floods (Sustainable Food Center Employee, December 12, 2017). For this, and numerous other reasons, almost all professionals recommend using native or naturalized plants in the projects. Not only can these plants better tolerate Central Texas conditions, but they also usually attract and provide resources for native pollinators. Interviewees also highlighted the importance of designing for native pollinators and not for honey bees. As previously mentioned these pollinators tend to be ignored by the public and are critical to local ecosystems.

Food resources for pollinators should be provided year-round. Although it was agreed upon that incorporating plants that bloom in at least three of the four seasons would be adequate for these small, self-implemented projects. One participant also mentioned that bees collect pollen from one type of flower before moving on to the next type of flower. Generally, pollinators need a clump of the same species of flower around a meter wide for the resource to be worth the energy expenditure of collecting nectar (The Nature Conservancy employee, December 1, 2017). Creating nesting habitat within the project is also just as important as providing access to food and water. Several species of native pollinators need exposed soil, deadwood, or other debris to nest in. However, a central problem with designing for increased biodiversity and heterogeneity is that these characteristics tend to be mistake for a lack of care (Nassauer, 1995, p 163).

This apparent disconnect between the scientific concept of ecology and the cultural concept of nature is essentially a design problem. The “nature” that North Americans have come to identify as “healthy” is more closely related to an antiquated concept of picturesque beauty than ecological function. This can be seen in people's characterization of Austin creeks and in the aesthetic preferences

of public parks (Coyne, 2015). In everyday landscape, rather than simply designing to enhance ecological quality we must design to frame ecological function within a recognizable system of form. It is important to design landscapes with a knowledge of the user's existing tolerance for messiness and perceptions about landscapes. Though people may care about improving ecosystem health, they likely will not sacrifice their aesthetic preferences for their landscape. People create landscapes to communicate belonging in their community or pride to their neighbors (Nassauer, 1995, p 162). If the community or neighbors do not perceive ecosystem function as beauty the owner will likely not pursue it.

Rectifying this disconnect is not a straightforward process, it requires the translation of ecological patterns into cultural language of landscape perceptions. Placing unfamiliar and frequently undesirable forms inside familiar and recognizable landscapes. One method is to design for hidden biodiversity. For example, The Lady Bird Johnson Wildflower Center recommends a technique called "stacking diversity," where you clump several different plants that look very similar (Wildflower Center employee, November 7, 2017). This creates the illusion

of one group of plants while accomplishing an increase in biodiversity; thereby limited the messy look of a garden but increasing ecological function.

Additionally, bee hotels can be a more attractive way to incorporate some of the dead wood and debris that native pollinators need for nesting. Bee hotels are more aesthetically pleasing to humans than piles of dead logs or plant debris, but patches of bare soil will still need to be exposed. Cinder blocks filled with woody debris, stems, dirt, and leaves can also be used to create more visually attractive shelter for native pollinators. Both of these artificial habitats can also be easily built by volunteers or school children. Wherever possible, educational outreach should be used to increase people's tolerance for “messiness.” Signage can spread awareness on the importance of these “wild” components of landscapes and to potentially change people's perceptions on beautiful green space.

Deadwood is an incredibly important habitat resource, especially in riparian zones such as along Waller Creek (COA Parks and Recreation Department, January 19, 2018). It provides habitat for pollinators as well as other forms of wildlife such as lizards, fish, or birds. In the past, fallen trees and deadwood were removed by city staff and contractors to create a more

manicured creek aesthetic, as desired by the public. But now the city has realized the importance of this resource and is working to preserve important fallen trees. The city provides a "Deadwood Stamp" which signals any workers this log is ecologically significant and should not be removed. The stamp also functions to educate the public on the importance of deadwood to urban wildlife. Citizens can apply to have a log or fallen tree on their property stamped so it won't be accidently removed. The city also recommends placing logs and other woody debris in secluded areas of green spaces or gardens to allow for natural decomposition to create habitat and soil building (Benefits of Deadwood, 2014).

Figure 7. City of Austin Deadwood Stamp.

Source: http://www.austintexas.gov/blog/benefits-dead-wood

Maintenance & Community Engagement

Several interviewees recommended planning for maintenance before the project is developed. One participant recommended a hybrid maintenance strategy similar to the one used at The Lady Bird Johnson Wildflower Center (Wildflower Center employee, November 7, 2017). The Wildflower Center relies on a combination of staff and trained volunteers to maintain their entire park. The Wildflower Center relies heavily upon a special group of volunteers called,

"docents." These are volunteers who have completed a two-part learning program and thus are trusted to represent The Center publicly. These docents answer questions from the public and help to train and recruit other volunteers. Through case study analysis and professional interviews, it seems one of the best way to plan for maintenance is to incorporate safe-to-fail strategies like relying on multiple groups for ongoing maintenance. This way maintenance is likely to be more comprehensive provided the different groups can communicate effectively.

Leadership and group hierarchy are important for lasting maintenance and for establishing effective communication between groups. An interviewee who works at the Sustainable Food Center suggested that creating groups who take ownership of the habitat will be beneficial to the project's long-term success. But for these groups to be effective and communicate well with volunteers and public administrations it is important for them to establish a leadership hierarchy and to undergo some leadership training (Sustainable Food Center Employee, December 12, 2017). This will create on the ground stewards who can closely monitor the project and advocate for it. A sense of ownership will also help to

ensure lasting maintenance and project success. She also suggested these groups seek training about gardening for pollinators.

The Sustainable Food Center offers multiple free leadership trainings as well as some free home gardening trainings. Although these trainings mostly discuss food gardening, which entail different maintenance techniques than pollinator gardens. Food producing plants tend to be annuals, meaning the plant dies after the growing season and needs to be removed. Whereas most pollinator plants are perennials that will return year after year unless they die. For this reason, food gardens need to be replanted after every harvest while pollinator gardens generally will not. So, while the maintenance techniques of these trainings may not be completely applicable, it is still suggested that someone within the project stewardship groups take a leadership training to learn effective communication, time management, and community engagement (Sustainable Food Center Employee, December 12, 2017).

Interviewees were also asked who they believe should be involved with the stewardship of Waller Creek. For the northern section of Waller Creek, interviewees listed several groups of people and individuals they believe should be involved in the stewardship of these projects and Waller Creek. These include

but are not limited to: landowners, local community members, schools, researchers, and other organized groups such as The Lady Bird Johnson Wildflower Center, The University of Texas, Friends of Shipe Park, The Nature Conservancy, City of Austin, and possibly the Waller Creek Conservancy (Wildflower Center employee, November 1, 2017; Jha Lab employee, November 27, 2017; Wildflower Center employee, November 7, 2017; Sustainable Food Center Employee, December 12, 2017; Watershed Protection employee, November 6, 2017, The Nature Conservancy employee, December 1, 2017, COA Parks and Recreation Department employee, January 19, 2018; COA Watershed Protection Department employee, November 6, 2017).

Native Pollinators and Plants of Waller Creek

The Jha Lab is a conservation biology lab at The University of Texas at Austin that investigates ecological and evolutionary processes from genes to landscapes, to quantify global change impacts on plant-animal interactions, movement ecology, and the provisioning of ecosystem services (Welcome!, n.d.). Although the Jha Lab specializes in researching pollinators and factors affecting them across the globe. Dr. Jha along with her colleagues and students have conducted numerous pollinator surveys across Austin and have identified native

pollinator species found near the study area for this thesis. These species were found at the Brackenridge Field Lab, which is a good representation of native pollinator species found in my study area (Jha Lab employee, November 27, 2017). These will be the target species recommended for pollinator-focused green infrastructure designs within the study area.

Table 3. Native Pollinators Found Near Study Area.

Bees	**Ground Nesting**	Green Sweat Bee (2 species), Striped Sweat Bee, Dark Sweat Bee (6 species), Mining Bee, Digger Bee, Chimney Bee (2 species), Plasterer Bee, Longhorn Bee (4 species), American Bumblebee, Squash Bee, Sunflower Bee (3 species)
	Wood or Cavity Nesting	Small Carpenter Bee (3 species), Mason Bee, Leafcutter Bee (6 species), Cuckoo Bee
Butterflies	**Specialist Larvae**	Dunn Skipper Butterfly, Clouded Skipper Butterfly, Eufala Skipper Butterfly, Small Sulfur Butterfly, Pipevine Swallowtail
	Generalist Larvae	Common Buckeye Butterfly

Not all bees create hives; in fact 90% of bees are solitary bees, meaning a single female makes a nest and cares for her eggs. Some bees will cohabitate in

the same nest but separately care for their own eggs and some are semi-social meaning they share the labor of collecting pollen and caring for young. Tropical bees and honey bees are social and will build large hives, these are the nesting characteristics that people are most familiar with. Generally, native bees can be characterized into two groups based on their nesting habits; ground nesters and cavity nesters.

Most native bees (around 70%) can be characterized as ground nesting bees. These ground nesting bees, as the name implies, burrow into the ground to take shelter and create nests for their young. Some dig tunnels underground and some build little chimneys, but it is important to note that all of these bees need loose, uncompact soil. For these reasons, pollinator habitat needs exposed patches of loose soil or sand. Cavity nesters use crevices or holes in rocks or soft wood and might cut leaves or use mud plaster to line and seal their nests (About Native Bees, n.d.). These bees used deadwood or other debris to build their nests and would inhabit the bee boxes or filled cinder blocks.

Another way to categorize pollinators is by their food requirements. Pollinators, and other wildlife, can be either generalists or specialists. Generalist bees are able to collect pollen from multiple plant families while specialists can

only obtain pollen from one species or one family of plants unless severely stressed by environmental factors. Squash bees for example, prefer to collect pollen from pumpkins and zucchini while cactus bees prefer prickly pear. These bees will collect pollen from other plant families but only under dire circumstances (About Native Bees, n.d.). Butterflies can also be broadly characterized by the food requirements of their larvae, or their young. Specialist larvae can only feed on a few select species from one plant family, while generalist larvae can feed on multiple species from more than two plant families (Treviño, Ballare, & Jha, n.d.). To attract these specialist pollinators, habitats need to include their preferred food source.

The Lady Bird Johnson Wildflower Center has a complete index of plants that are important for native bee populations in the Austin area (Special Collections, n.d.). And the Jha Lab has many tips on creating native bee habitats; these links will be provided in the attached handout at the end of this report (About Native Bees, n.d.). Those who wish to implement pollinator habitat should also use the plant database from The Wildflower Center and the native plant database from the City of Austin to choose their own plants based on their garden constrictions.

STAKEHOLDER SURVEYS

After the professional interviews were conducted, surveys were distributed to stakeholders in the Northern Waller Creek Area. The target audience was defined as anyone who lives within the study area or is invested in the wellbeing of the study area. Surveys were conducted in two rounds. Answers from the first round indicated that respondents were confused or didn't understand some of the questions. One such question asked respondents if they were familiar with a pollinator garden; nearly every respondent answered with a simple yes. After that first round, some questions were rewritten to be clearer and elicit more detailed responses. The question asking if they knew about pollinator gardens was rewritten to ask them to define a pollinator garden in their own words. This allows me to determine if there are any fundamental misunderstandings or assumptions.

The first round of surveys was distributed at a monthly meeting for the Hyde Park Neighborhood Association. Eleven responses were collected during this round. As expected from a homeowner's association meeting, ten out of the eleven respondents were homeowners. The second round of surveys was distributed at an "It's My Park Day" event at Shipe Park. It's My Park Day is a city-

wide, volunteer event to maintain parks and green belts which takes place twice a year. Shipe Park is a small, neighborhood park located within Hyde Park and adjacent to Waller Creek. Twenty-four surveys were collected during this event. One additional survey was collected from a coworker at the City of Austin.

In total thirty-six surveys were collected over a month during the two rounds of distribution. Forty-two percent were renters and fifty-six percent were homeowners, with one person refusing to answer the question. Respondents were asked about their familiarity with the term "pollinator garden." Out of the thirty-six responses, four were somewhat familiar with a pollinator garden and nine did not know what a pollinator garden is. From the definitions provided in the second round, it was clear that multiple people thought they understood pollination and the concept of a pollinator garden but were unknowingly incorrect. Several people seemed to be confused about the principles of pollination in general; they seemed to think it had something to do with seed dispersal and not pollen. For example, one definition of a pollinator garden stated, "A garden where insects can eat and spread seeds - particularly bees." Three similar responses were given, all confusing the concept of seed dispersal

with pollination. While this confusion is understandable, it means that education provided in the habitats should cover the concept of pollination as well.

As mentioned in the example above, out of the responses indicating a lack of knowledge about pollinator gardens, many respondents also seemed to be fixated on bees as the only pollinators. While several people were able to correctly define a pollinator garden, many were confused about the fundamental basics of pollination and saw bees as the only pollinators. This indicates that when the public is educated about the pollinator habitat projects, we should begin with basic education on pollination and different pollinators. A pollinator garden definition was counted as correct if it mentioned plants attracting pollinators. Usually if a respondent correctly defined a pollinator garden, they identified birds, bees, or butterflies all as pollinators.

Respondents were also asked to identify their top three obstacles or limiting factors if they were to try to install a pollinator garden. The complete list of factors to choose from is available in the surveys located in the appendix and in the following tables. The number one obstacle listed by respondents was "limited space or lack of sunlight" with eleven respondents ranking it first. However, "maintenance" was ranked within the top three obstacles twenty-three

times and “limited space or lack of sunlight” was only ranked in the top three sixteen times. This indicates that while “limited space or lack of sunlight” is an initial concern for many people, maintenance is the largest obstacle overall.

The total responses for obstacles ranking either first or appearing in people’s top three are detailed in the table below. The two “other” answers from respondents were as follows: “No water” and “My son is very afraid of bees and won’t go outside if there are bees in the yard.” The respondent who responded “No water” indicated that they have difficulty gardening in Texas and have only been able to keep succulents alive. The second respondent mentioned they would like to have a pollinator garden but are worried about their son staying inside because of his fear of bees.

Table 4. Obstacles or Limiting Factors Ranked First or Ranked in the Top Three.

Obstacle or Limiting Factor	Ranked First	Ranked in the Top Three
Limited space or lack of sunlight	11	16
Maintenance	7	23
Cost	5	12
Permission from a landlord	3	7
Not enough time	2	8
Help with installation	2	9
Concern about bees, pests, or pollen allergies	1	6
Other (Please list)	0	2
Poor aesthetics	0	2

Respondents were also asked to rank the top three motivating factors for them to install a pollinator garden. The complete list of choices is available in the surveys located in the appendix and in the table below. "Benefits to pollinators" was ranked as the number one motivating factor twelve times. While overall the motivating factor listed most frequently within respondents top three was "benefits to the environment" with "benefits to pollinators" as a close second. Below is table outlining the top ranked motivating factor as well as the top three rankings.

Table 5. Motivating Factors Ranked First or Ranked in the Top Three.

Motivating Factor	Ranked First	Ranked in the Top Three
Benefits to pollinators	12	27
Community engagement	9	13
Benefits to the environment (reduced flooding, cleaner air, etc.)	8	31
Aesthetics	5	18
Educational benefits	2	10
Additional benefits (Food production, etc.)	0	7
Other (Please list)	0	0

These surveys with residents and stakeholders of Waller Creek produced great insight into the public's perception of pollinators and gardening in general. One respondent indicated they were disheartened because they had planted a pollinator garden, but moths had laid eggs and eaten all of the plants. Once realizing that moths are also pollinators and that pollinator plants are supposed to be eaten by pollinators the respondent seemed to be happy the garden had performed its function. This lack of understanding that plants will be consumed in the early stages of a pollinator's life was echoed in one of the interviews with a City of Austin employee. This interviewee mentioned they receive questions about how to make a pollinator garden but also keep out caterpillars and other perceived pests (Watershed Protection employee, November 6, 2017). It seems that when the public think of pollinators they think of only the adult stages and not the earlier stages of life. Perhaps it is ingrained in us to react badly to things eating the plants we have cared for.

In response to this sentiment, the City of Austin Watershed Protection Department has created a guide to identify beneficial insects in a garden. The guide mentions that more than ninety-five percent of beneficial insects either eat pests or pollinate plants. The guide identifies common beneficial insects and

outlines why they are beneficial. The Watershed Protection Department also provides a guide to beneficial caterpillars. The guide details which caterpillars are pests, and which are actually butterfly larvae. While this guide is not a comprehensive list to caterpillars in Austin its main job is to illustrate that not all caterpillars are pests. To implement true pollinator habitat, caterpillars need to be provided for and the user need to understand their importance. Plants that host larval stages of insects are going to be eaten, and that is okay.

Site Designs

To provide guidance for people who have little to no familiarity with pollinator habitat or pollinator-focused green infrastructure, I have created two examples of such projects. These are developed with the intention of being visual representations and examples of how the different components of pollinator-focused green infrastructure can be incorporated into small spaces. Neither of these projects are currently planned to be implemented, since it is outside the scope of this research. However, after the conclusion of this study, I plan to

release the proposals to both The Commodore Perry Estate and Russell Lee Elementary School with the permission to implement the designs.

Each site was designed by using the pollinator species plant list from The Wildflower Center and the native and naturalized plant guide from the City of Austin to identify native or naturalized plants for the target pollinator species. Areas with potential sites within the study area were identified based on the point of interest map outlined in the research design and methods section. These were selected if they were located within a quarter mile of Waller Creek, were near either a school or large green space, and did not have existing pollinator-focused green infrastructure onsite. Based on the literature review and case study analysis, we can assume that green infrastructural designs change depending on the site, intended use or users, and surrounding built environment. In addition to providing visual references, these two examples explore the differences in designs resulting from different sites, intended use or users, and characteristics of the surrounding built environment.

The first site is located in the private yard of Russell Lee Elementary School located a few blocks north of The University of Texas near Red River Street. The school is surrounded by residential homes to the north, east, and south and

borders Waller Creek to the west. I wanted to explore the difference design requirements and maintenance strategies of a public, community park and a private, educational pollinator garden for children. The second site is an undeveloped portion of the Commodore Perry Estate, which could be redeveloped into a neighborhood pollinator park with potential for food gardens or event gathering. The site is located just north of the Hancock Golf Course and is bordered by Waller Creek to the north and east, 41st street to the south, and residential homes to the west.

DESIGN 1: LEE ELEMENTARY POLLINATOR GARDEN

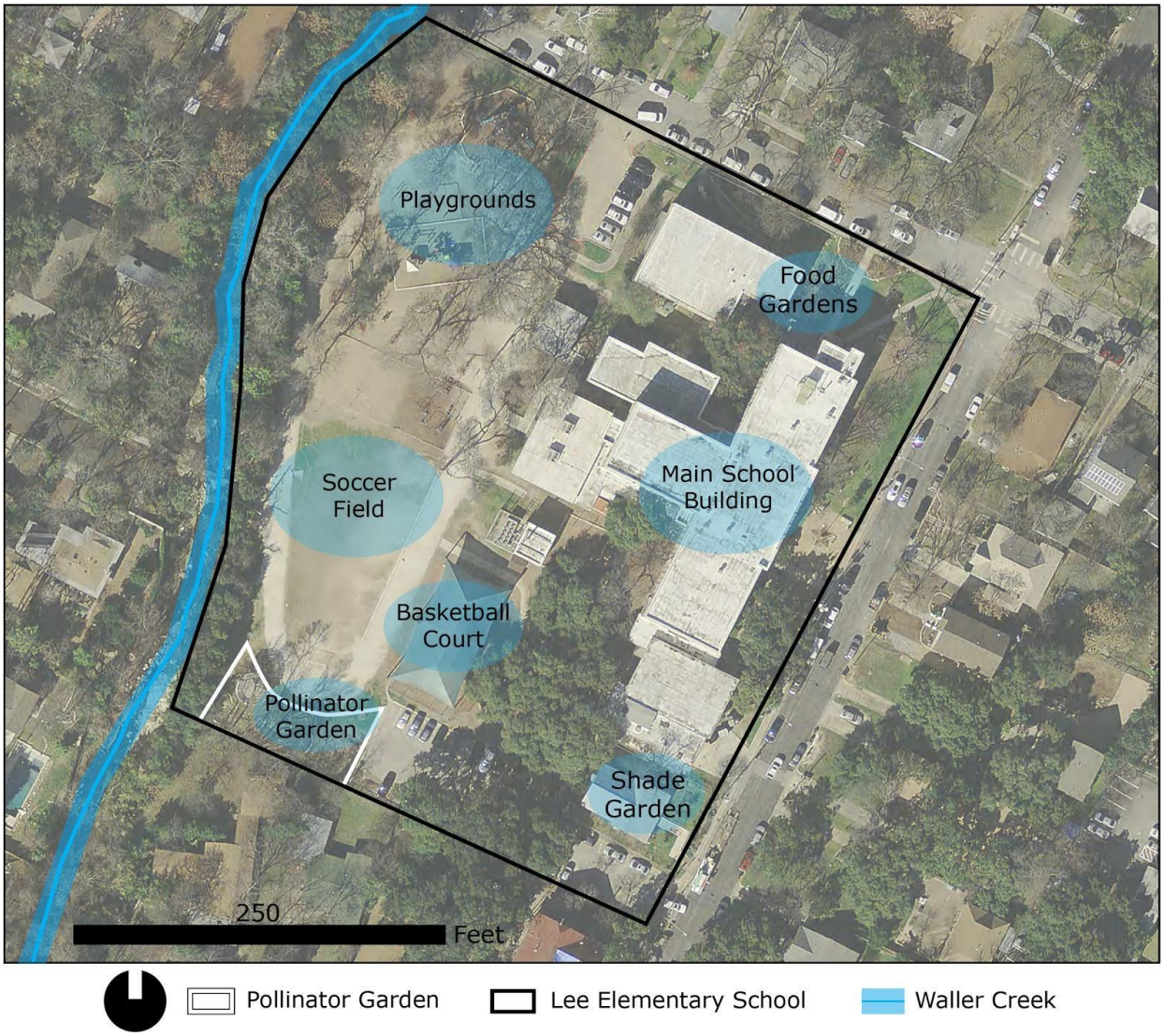
The Site

Russell Lee Elementary School is a public elementary school located within the urban core of Austin, just north of The University of Texas at Austin campus. The school property is approximately 4.5 acres in total and houses several school buildings as well as outdoor play areas. Waller Creek runs along the western edge of the property, this particular section of the creek has large, limestone shelves ideal for the children to observe the creek without getting in the water. The school's principal has built a path down to the limestone shelf along the creek for

the students to be able to access the creek for educational purposes. These limestone shelves are also ideal water resources for pollinators due to the frequent shallow puddles.

The principal at Lee Elementary believes that children, especially those who live in urban areas and may not have equitable access, should have the opportunity to experience nature. Lee Elementary school has a plethora of hands-on outdoor experiences for the children. The school has a commercial food garden which is planted and maintained by Lettuce, an urban farming group that sell crops grown on underutilized urban land such as schools or churches. The garden is maintained by the Lettuce group, but the children get to watch and learn about a commercially productive garden. The school also has a few small herb and food gardens, shade garden, and a chicken coop which are all cared for by the students.

Map 3. Lee Elementary School Existing Site Map. Created by Nathlie Booth.



All landscaping maintenance for the school is done by a group of volunteer parents called “The Roadies”, named after the school’s roadrunner mascot. Current maintenance is pesticide free, except when there are fire ants in the playground. But even in those instances, the school tries to use natural or less

harmful pesticides. During the summers, although the school building is vacant, the chickens still require care so a rotating group of parents or the principal are given access to maintain gardens and care for the chickens. Although very little garden maintenance is done during this time, usually just some occasional watering. Since all landscaping is done by volunteers, the maintenance protocol at the school is flexible. Meaning that any changes required to be made to the existing maintenance plan are as simple as teaching the volunteers.

The Design

Maintenance for the proposed pollinator garden will completely rely on these social systems of parents and school staff. For this reason, the pollinator garden will be designed to be as low maintenance as possible. The location for the garden is an unused portion of the school yard in the southwest corner. This portion of the yard is approximately one-tenth of an acre or 4,852 square feet, has a small drainage channel, and a pavilion used for outdoor classes which makes it an ideal location for an educational pollinator habitat. The occasional flow of water through the site will provide water for pollinators, plants, and facilitate some decay and softening of the woody debris for habitat. Since the

location is in the corner of a school yard, the space can also be wilder than the second site. More wildflowers and less ornamental plants will be used as these require less maintenance but also create a more unmanaged aesthetic. However, children enjoy using their imaginations to explore perceived wild landscapes. This garden will safely replicate a natural stream and be designed for interaction between children and nature. The wild design will lower maintenance, create a more active habitat for pollinators, and perhaps a more exiting landscape for the children.

The goal for this site will be to provide a lively, active habitat for pollinators with ample educational and observation opportunities for the children. To lower maintenance, plants should be planted as close together as possible, this will eliminate some of the need to weed and increase biodiversity in the site. Additionally, the drainage channel should be designed to more closely resemble a stream bed, with varying sizes of rocks and logs as seen in the rendering below. The logs and rocks will provide additional habitat for the bees while creating a more aesthetically pleasing drainage system. The drainage channel should meander like a natural creek, this will slow the flow of water and

lessen the impact of erosion. This rocky stream bed design can also be rearranged by the children during recess without affecting the functionality.

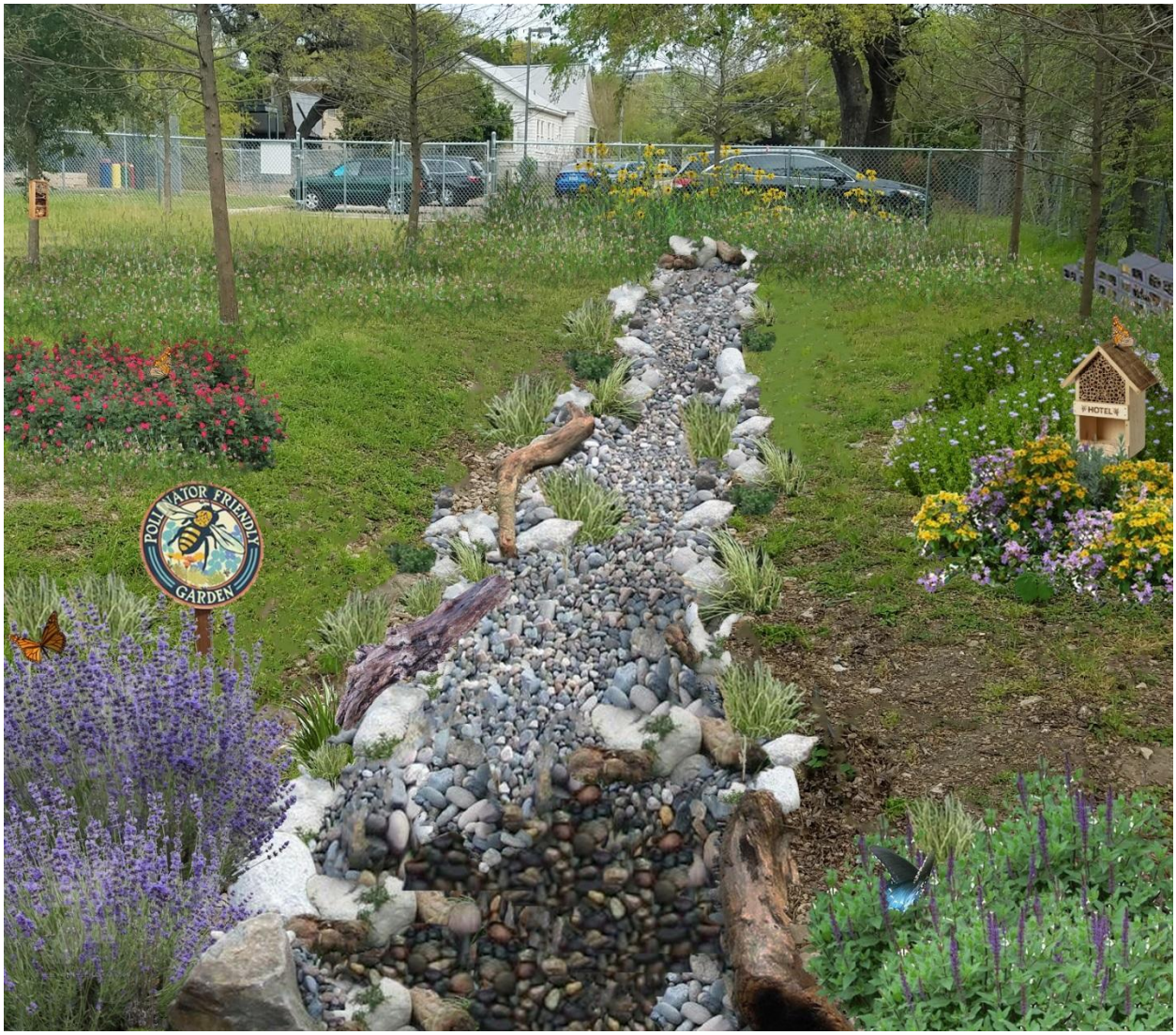


Figure 8. Rendering of Lee Pollinator Garden. Created by Nathlie Booth.

Multiple types of artificial habitat should be incorporated into the site to increase the chances of attracting pollinators. Whenever possible, the children should be involved in the implementation of this garden. This will create a stronger connection between the children and the garden as well as provide educational opportunities. Children can help build bee hotels by filling cinder blocks or wooden structures with mud, bamboo stems, leaves, and soft wood. They can also help plant the clusters of flowers or scatter seeds for a wildflower meadow. Bee hotels can be hung from the pavilion roof, mounted on posts, or placed directly on the ground so long as they receive ample direct sunlight. These can also be built by the children, purchased in some gardening stores, or donated by volunteers.

Figure 9. Example of Cinder Block Artificial Habitat. Created by Andrea Reid.

In addition to being more ecologically significant, most native bees are non-aggressive, do not swarm, and do not sting. While some parents may feel trepidation about a pollinator garden being located in the playground, the secluded corner location and emphasis on native pollinators should provide some comfort. As seen in the New Zealand case study, educational outreach will be key for the success of this garden. It is important that information about native pollinators be provided at the beginning of the project to assuage any fears and misconceptions from parents and children. Due to the varying reading levels of elementary school children, the most helpful education about the garden will come from teacher explanations. Educational signage should be used in this habitat to identify plants and describe basic concepts of pollination and native pollinators.

Plants selected for this site are all shade tolerant since there are multiple trees nearby. This design explicitly provides food and host resources for four target species: Pipevine Swallowtail Butterfly, Monarch Butterfly, Small Sulfur Butterfly, and the Sunflower Bee. Although by planting squash, zucchini, or pumpkin in the nearby food gardens the pollinator garden can provide habitat for Squash Bees as well. Planting similarly colored flowering species close

together will lower maintenance requirements while providing optimal food resources for pollinators as shown in the site plan below. Planting the same type of flower in large clusters make resources collection easier for pollinators.

This garden is designed to be wilder and more productive than the neighborhood pollinator park. Aesthetics are not as important for this site as observable productivity. Children would rather have a lively pollinator garden than a pretty one. Since the school will be vacant during the summer, the garden should be designed for low maintenance in the summer. Luckily, as long as the bee hotels are placed in sunny spots and plants are watered occasionally it should be fine. Although there is a chance that the bee hotels will need to be covered or cared for in cold months. Below is a detailed design for the site including a plant selection. The bottom corner, closest to the creek, should be designated as a deadwood habitat. The soil in this spot should be kept from becoming compacted to provide habitat for ground nesting bees.

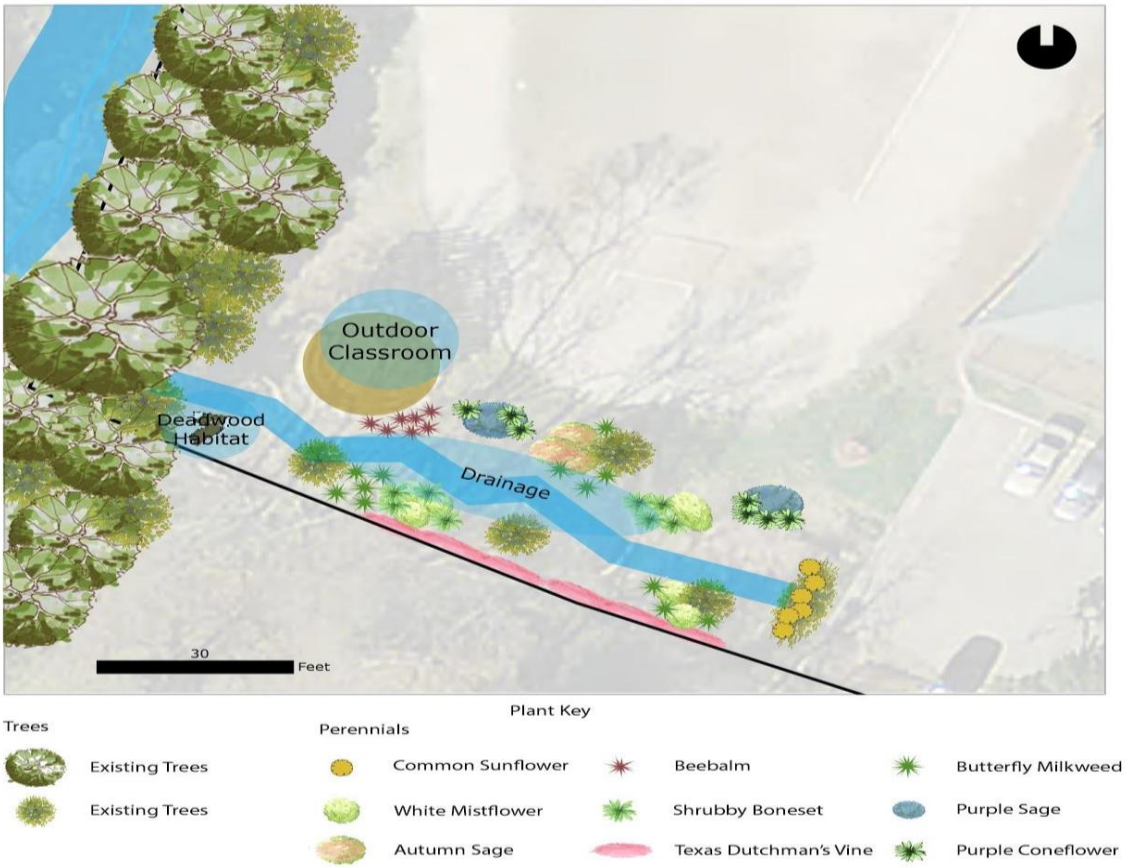


Figure 10. Lee Pollinator Garden Site Plan. Created by Nathlie Booth.

DESIGN 2: NEIGHBORHOOD POLLINATOR PARK

The Site

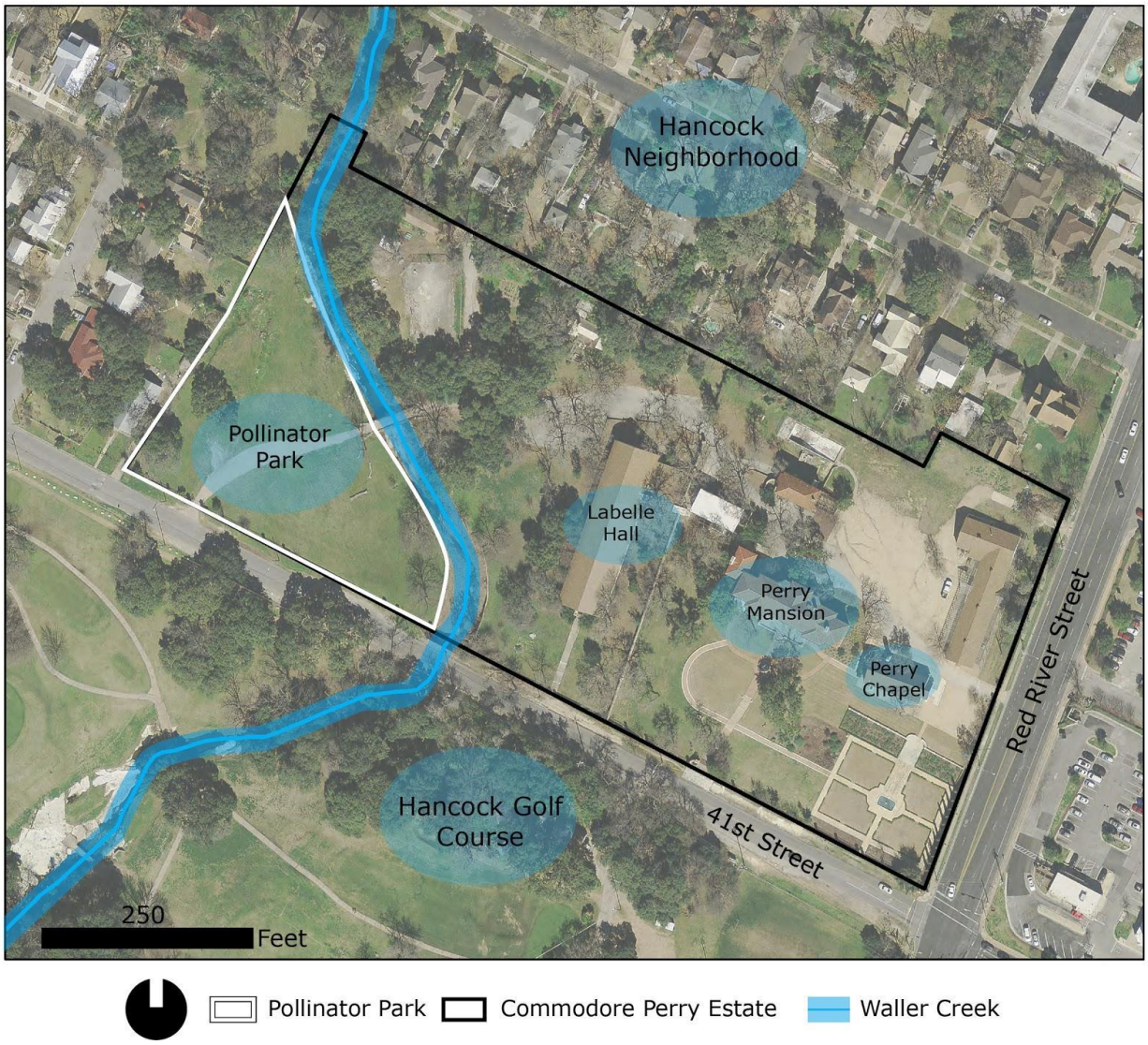
The second example site is located within the study area adjacent to the northern edge of the Hancock Golf Course. The site was chosen because of its

proximity to the largest green space in the study area (Hancock Golf Course) and its adjacency to Waller Creek. The site is an undeveloped portion of the Commodore Perry Estate, a 10-acre lot that houses a historic mansion and seven other structures. The Estate was built in 1928, and over the years has housed the Perry family and at least seven private schools. The Estate is currently abandoned and has been the recent target of arsonists. The Commodore Perry estate holds historic significance as a center of education and community events for the Hancock neighborhood. The current owners plan to renovate the estate and its structures into a boutique hotel. I propose that roughly one-and-a-half acres of the 10-acre lot be developed into a community pollinator garden for the Hancock neighborhood and the new hotel.

The southwest corner of the lot is separated from the rest of the land by Waller Creek. This portion of the Commodore Perry estate would make an ideal location for a community pollinator garden because of its natural separation from the proposed hotel and easy public access. With the addition of a gazebo the garden could also be marketed as a wedding venue or event space. Converting this currently empty and unused portion of the land into a pollinator garden preserves the history and character of the estate while adding function,

community connection, and beautification. Additionally, it seems the owners wish to make the property more accessible to the community and to highlight the important local significance of the estate. Emily Little, principal at Clayton & Little Architects designing the renovation, stated in an interview with the Austin American Statesman, “The new vision for this property will make it accessible for more people in the surrounding neighborhood and beyond to enjoy” (Novak, 2017). The addition of a public pollinator garden supports and emphasizes their commitment to the community.

Map 4. Commodore Perry Estate Existing Site Map. Created by Nathlie Booth.



The Design

I am operating under the assumption this site will be a pollinator garden that is open to the public but maintained and owned by the Commodore Perry

Estate or proposed hotel. This necessitates simultaneous needs for open public access and private control. The lot is currently surrounded on all sides by both a gated wall and Waller Creek. Therefore, the Estate could easily enforce visiting hours to the park should they wish to impose them. This one-and-a-half-acre portion of the estate has ample space for programming such as a food garden, a gazebo, and wildflower meadow. This empty lot can be transformed into a beautiful, inclusive space that provides community amenities as well as a public avenue to the hotel. The focus of this garden will be to create a welcoming pollinator garden for the public while also beautifying the hotel grounds and adding function to an undevelopable space.

A majority of this site is located within the 25-year floodplain for Waller Creek. I suspect this is why it has remained untouched through the history of The Estate. According to the City of Austin Watershed Protection Departments floodplain regulations, Land Development Code chapter 25-7, development within the 25-year floodplain is severely limited. That being said, Watershed Protection has approved community gardens in the 25-year floodplain, though depth of the floodplain and location of the garden within the floodplain plays into the approval. Structural certification would be needed for any 'permanent' or

large structure (e.g. benches, fences, trashcans, large bee hotels, gazebos, pergolas, sheds, bridges, large didactic panels, etc.), but structural certification would not be needed for smaller or at-grade items (e.g. pathways, pole-style bee hotels, garden beds, small signs indicating that the area is wildlife habitat, etc.). For this reason the gazebo has been located outside the 25-year and 100-year floodplain onsite. The only development within the floodplain will be small objects that do not need structure certification and possibly redeveloping the existing bridge crossing Waller Creek. Everything on site would need to be certified to have no adverse impact on the floodplain and seek approval from the Watershed Protection Department, but by following my design this project could be implemented fairly easily.

Map 5. Commodore Perry Estate Floodplains. Created by Nathlie Booth.

To establish this as a pollinator habitat, the entire estate will need to be maintained without the use of pesticides or herbicides. I have designed this garden to require a higher level of maintenance than the first site example, as the proposed hotel will likely prefer a more manicured aesthetic. More ornamental

plants have been selected as opposed to wildflowers and grasses which would create a wilder aesthetic as seen in the first example. Since this site is larger than the school garden, I have also recommended planting several trees. Special care must be taken to ensure the soil on site does not become too compacted by visitors; this will adversely impact the ground nesting pollinators.

Hotels and public gardens usually prefer more manicured green spaces. While I am hoping this perception can be changed over time, I will design this space to be more manicured while maintaining functional biodiversity. The secluded, top corner of the lot should be designated as a deadwood habitat for cavity and ground nesting bees since it is near the water and out of the way. Bee hotels and educational signage can be placed along a gravel path leading to a new bridge crossing the creek. The signage should educate the public on the importance of pollinators as well as the significance of design aspects like the deadwood and bee hotels. The gazebo should be large enough to hold a small wedding or band. Community gardens can be included onsite and rented to the surrounding neighborhoods. Or if the hotel plans to include a restaurant, they could plant a kitchen garden to grow some of a restaurant's ingredients. Being so close to Waller Creek, flooding will likely be a concern for the hotel. A natural riparian

buffer should be maintained along the creek edge to facilitate passive water filtration and create a natural riparian buffer.

Figure 11. Neighborhood Pollinator Park Site Plan. Created by Nathlie Booth.

Broadly the functional goals for this design are to support native pollinators, engage the local community with the proposed hotel, and to restore some ecological health and function to Waller Creek. The importance of each design aspect is highlighted in the image below. I expect that maintenance of the food gardens will be under the responsibility of the community members renting the plot or perhaps the hotel if they use the space for a farm-to-table garden. It is also possible that occasional maintenance of the pollinator park could be done by a volunteer group, like the "Its My Park Day" volunteer maintenance.

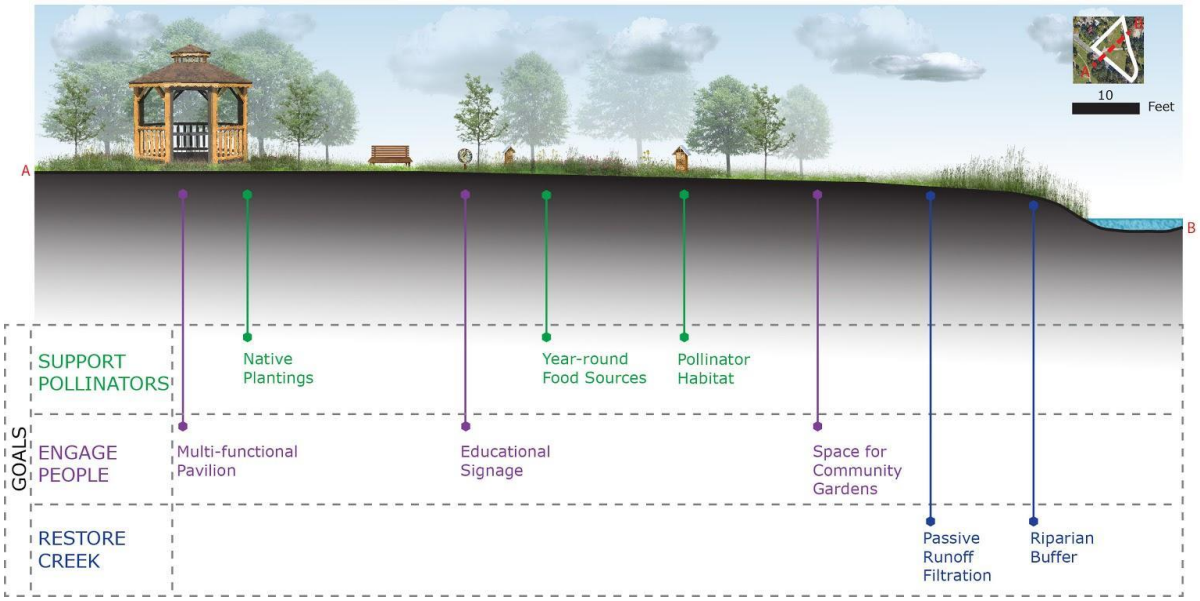


Figure 12. Neighborhood Pollinator Park Section. Created by Nathlie Booth.

CHAPTER 4: RESULTS

Discussion

The goal of this research is to better understand what people can do to ensure the vitality of urban ecosystems and to encourage citizens to become stewards of their environment. By establishing multiple small pockets of pollinator-focused green infrastructure along Waller Creek and encouraging more pollinator friendly maintenance methods we can create a pollinator corridor with the creek as the spine. From the stakeholder surveys and professional interviews, I can conclude that there is significant public interest in supporting urban pollinators and beautifying Waller Creek. Hopefully, with some guidance provided by this thesis more people will implement projects to improve ecological functionality of the northern Waller Creek watershed.

Several applicable lessons have been learned from the data collection and methods of this research. First, green infrastructure that supports pollinators should be implemented in underutilized spaces so as not to contribute to urban sprawl. This is good news for stakeholders and local communities. It is far more ecologically effective and cost effective to use the underutilized space they likely

already have than to obtain new or larger pieces of land. As seen in the example site designs, effective pollinator gardens can be implemented in small areas. If food, shelter, nesting, and water resources are provided for the various stages of the pollinator's life, pollinator habitats should be successful and ecologically productive.

Second, long-term maintenance is required for successful green infrastructure. Green infrastructure typically requires more maintenance than grey infrastructure over the projects life. Based on this research I recommend creating a maintenance plan before the project is developed. Through case study analysis and professional interviews, it seems the best way to plan for maintenance is to incorporate safe-to-fail strategies like relying on multiple groups for ongoing maintenance. A hybrid maintenance strategy like the one used at The Lady Bird Johnson Wildflower Center and in the Grey Lynn Pollinator Path case study is likely the most effective solution. Transdisciplinary cooperation usually between local communities and city government is needed for long-term maintenance.

Many green infrastructure projects encounter problems with maintenance because people tend to think in periods of twenty years instead of one-hundred

years. Long-living green infrastructure projects that do not plan to be rebuilt after thirty or fifty years require involvement at all levels. However, communication and organization of all involved parties are essential for success. Leadership and group hierarchy of volunteer communities are important for lasting maintenance and for establishing effective communication between different groups. After this research, I would recommend that civic environmentalist groups involved in green infrastructure projects undergo some leadership training and perhaps gardening training as well.

When communicating effectively, this combination of activist groups and institutional oversight can be lead to long-term maintenance and project success. "It's My Park Day" is a good example of this partnership between institutional maintenance and organized volunteers. Public parks are maintained by city staff, but twice a year volunteers come together and provide a finer quality of maintenance while taking ownership of their space. Although civic environmentalism is great for project installation and occasional upkeep, there must be safe-to-fail systems in place to pick up the slack when volunteers are not reliable. The partnership between civic groups and institutions should be sufficient to supply these safe-to-fail systems.

The third lesson is that community engagement must be done properly for it to be useful. Educational outreach is key for public buy-in and support of the project. As seen in Sarah Bergmann's Pollinator Pathway, public perception and support can be a limiting factor in the project's success. It is unclear if Sarah could have done anything differently to educate the public about the meaning of her project or if the project was simply ahead of its time. If more homeowners understood the need for pollinator corridors and less people became fixated on saving honey bees, the Pollinator Pathway might have been completed. But when there is public enthusiasm and understanding of a project, civic environmentalism can go a long way towards a project's success. For example, Pollinator Paths met very little resistance from local communities because Andrea Reid educated people from the very beginning on the importance of her project. She spent a great deal of time passing out flyers and posting signs letting the community know what was happening and why it mattered. Civic environmentalism has been the driving factor behind the successful implementation and maintenance of the Grey Lynn Pollinator Path, without volunteers it is unlikely the project would not have been successful.

And finally, regarding the most important factors when designing pollinator habitat or pollinator gardens, interview participants gave several guidelines for designing quality pollinator-focused green infrastructure that should be passed on to those who wish to implement their own. When designing pollinator habitat is it important to plan for biodiversity, design for the entire lifespan of a pollinator, pay attention to soil and sunlight conditions, plant clusters of flowers that are a meter wide, target specific pollinator species, understand the user's tolerance for "messy" landscapes, and provide year-round necessities for pollinators including dietary variety.

Habitat needs to at a minimum provide the following four things: native plants that produce year-round food, a reliable water source, safe places for wildlife to hide from predators and to shelter from the weather, and nesting boxes or places for pollinators to raise their young. People tend to overestimate the amount of space to leave between plants. This will require more maintenance in the form of weeding. Also, placing plants with similar water and sunlight requirements together will make maintenance easier. To implement true pollinator habitat, caterpillars need to be provided for and the user need to

understand their importance. Plants that host larval stages of insects are going to be eaten and that is okay.

Conclusion

This thesis aims to help people understand how to create well-design habitats for urban pollinators in the Northern section of Waller Creek. Although most of the advice on gardening for pollinators is applicable across Austin. These habitats should complement each other and form a network to support urban species diversity and abundance. From this research, I can conclude that small-scale green infrastructure such as pollinator gardens or artificial habitats will improve habitat connectivity along the urbanized Waller Creek. Using the multi-functionality of green infrastructure to create a healthier urban environment within the already existing urban fabric.

This research identifies the pollinator-focused green infrastructure designs that are most likely to benefit the urban ecology of Waller Creek, how green infrastructure changes depending on the adjacent urban context and user requirements, and some common obstacles, perceptions, and motivating factors people face when implementing pollinator-focused green infrastructure. The

pollinator-focused green infrastructure designs are detailed in the professional interviews and the example site designs. These designs include specific ways to plant native and naturalized plants that attract pollinators, inclusion of nesting resources both natural and artificial, and water resources.

My hypothesis that designs for green infrastructure interventions and maintenance strategies will change depending on the surrounding built environment was correct, but not to the extent that I thought. Designs of green infrastructure depend mostly upon user needs and maintenance capabilities and less upon the adjacent built environment. The types of pollinator-focused green infrastructure used at different sites does not vary as much as I thought. The designs change the most based off the maintenance capabilities and programming needs required by the users. For example, the neighborhood pollinator park design creates a more manicured garden with space for events and requires a higher level of maintenance due to the aesthetic preferences of the hotel. The Lee Elementary Pollinator Garden design is wilder, designed to be much more educational for the children, and lower maintenance than the neighborhood pollinator park because it is maintained by volunteers.

My second hypothesis, that civic environmentalism and social systems are integral components of green infrastructure plans was also correct. My research expands on the notion of social systems as a vital part of green infrastructure interventions and the need for civic environmentalism to support small-scale green infrastructure. Social systems are essential for the care, maintenance, and sometimes implementation of living projects. Urban green spaces, are often highly managed and heavily influenced by human intervention to the point of ecological functions being intertwined with cultural functions. Vibrant social systems are essential for the long-term success of designed landscapes. The case studies, It's My Park Day type events, and the maintenance efforts of Lee Elementary are all examples of volunteer-based efforts to create successful green infrastructure projects. To that end, human connection to landscapes can be strengthened through the integration of diverse public preferences in landscape designs, education of people on sustainability through interactions with nature, recognition of the importance of personal and cultural connections to landscapes, and efforts to improve overall human health and wellbeing

Common obstacles, perceptions, and motivating factors were identified in the stakeholder surveys. These include perceptions of space or sunlight

limitations, concerns about overwhelming maintenance, misunderstandings about pollination, interest in installing pollinator gardens, and a desire to benefit pollinators and the environment. I hope that people find this thesis to be a useful guide and more pollinator-focused green infrastructure is implemented in Austin, including the two designs created by this thesis. After the conclusion of this study those designed will be released to the Commodore Perry Estate and Lee Elementary with the hopes they will be implemented.

Given more time, I would have also liked to investigate any overlapping ecological benefits of green infrastructure. The City of Austin Watershed Protection Department is working on a pilot program for rain gardens maintained by property owners in the Northern Waller Creek watershed. There is great potential for these rain gardens to be multifunctional and provide resources for pollinators. Austin is one of the fastest growing cities in the nation and as the city grows it places tremendous pressure upon our natural environment. Small scale, citizen installed and maintained green infrastructure projects are the best way to bolster the urban ecology of Austin without contributing to sprawl.

APPENDIX

Public Guidance Handout

Pollinator Garden Tips:

- To help plan your garden, pick a few pollinator species you would like to attract and provide resources specifically for them.
- You must provide year-round food sources, water, shelter, and nesting for your target pollinators.
- Use native and naturalized plants that can thrive in the Hill Country climate. (This will make gardening easier, too!)
- When planting, place plants close together. It is okay for plants to crowd each other a little and this will reduce the need to weed.
- Pollinators need meter-wide clumps of the same flowers to be able to efficiently collect pollen.
- Host plants for larval pollinators are going to be eaten, and that is okay.
- Know the difference between beneficial insects and pests.
- Amend soil as needed but be careful not to use chemical fertilizer and don't over fertilize! Over fertilization can pollute creeks and damage ecosystems.
- For community and school gardens: Create a maintenance plan at the beginning of the project. Decide who is responsible for maintenance and how often it should occur.

Public Guidance Handout (cont.)

Online Resources:

Plant databases:
Lady Bird Johnson Wildflower Centers Native Pollinator Plant List:
https://www.wildflower.org/project/pollinator-conservation

Central Texas Specific Database:
https://www.wildflower.org/collections/collection.php?collection=TX_central

City of Austin Native and Naturalized Plant Database:
https://austintexas.gov/department/grow-green/plant-guide

Habitat Certification and Guides:
City of Austin Pollinator Challenge:
http://www.austintexas.gov/pollinatorchallenge

- Pollinator Habitat Certification

City of Austin Grow Green:
http://www.austintexas.gov/department/grow-green

- Gardening fact sheets, design templates for gardens, rebates, free stuff, grants for school or community gardens, information on rain gardens and other beneficial gardens

City of Austin Integrated Pest Management:
http://www.austintexas.gov/ipm

- Beneficial insect guides, pesticide information, guides for environmentally friendly pest management, caterpillar guides, etc.

Public Guidance Handout (cont.)

Trainings and Classes:

Sustainable Food Center - Grow Local Programs:
https://sustainablefoodcenter.org/programs/grow-local

- Many resources for garden and leadership trainings, funding sources for school and community gardens, places to buy low cost tools and gardening supplies.

SFC's Grow Local Classes and Trainings:

- Community Intro to Food Gardening Classes
  - These classes cover the basics of starting and caring for a food garden.
- Public Intro to Food Gardening classes
  - Classes to equip Central Texas residents with the knowledge they need to start and sustain organic food gardens in their own space.
- School Garden Support & Trainings
  - Trainings to help teachers, parents, and community members in the Austin area start, use, and sustain successful school gardens.
- Community Garden Support & Trainings
  - Support and training to help Central Texas residents start and sustain a community garden by providing education, consultation, and fiscal sponsorship.
- SFC Teaching Garden Tours & Field Trips
  - J.P.'s Peace, Love, and Happiness Foundation Teaching Garden is SFC's site for gardening classes, hands-on, TEKS-aligned school field trips, volunteer work days, group tours, and self-guided visits. The Teaching Garden demonstrates sustainable food gardening techniques that are well suited to Central Texas' semi-arid climate.
- Spread the Harvest Project
  - Spread the Harvest seeks to reduce financial barriers to food gardening by providing Central Texas schools, low-income residents and not-for-profit gardens, and other groups with free gardening materials.

Professional Interview (Generic Version)

1. How long and at what capacity have you been involved with your field of study?

2. What is your experience with pollinators?

3. What programs or projects are you aware of that are benefitting pollinators?

4. In your opinion, what would be the three most important factors when designing pollinator gardens or habitat? And why? (Example: Connectivity, distance from cars, seasonal food access, avoiding pesticide, etc.)

5. Who do you believe are key people or groups of people who should be involved with the stewardship along Waller Creek?

6. Is there anything I have not asked that you wish to discuss?

7. Who do you recommend I contact next?

Stakeholder Survey (Version 1)

1. Do you own or rent?

2. Are you aware of the role pollinators' play in our lives?

3. Are you familiar with pollinator gardens?

4. Would you ever consider building a pollinator garden? If not, why?

5. Of the following, what would be the three biggest obstacles for installing pollinator garden?

   Please rank three of the following in order of importance (1=most important, 2=second most important, and 3= third most important)

_____Limited space or lack of sunlight
_____Poor aesthetics
_____Maintenance
_____Cost
_____Concern about bees, pests, or pollen allergies
_____Help with installation
_____Not enough time
_____Permission from a landlord
_____Other: *Please List:* _____

6. Of the following, what would be the three biggest motivators to install a pollinator garden?

   Please rank three of the following in order of importance (1=most important, 2=second most important, and 3= third most important)

_____Community Engagement
_____Aesthetics
_____Educational Benefits
_____Benefits to Pollinators
_____Benefits to the Environment (reduced flooding, cleaner air, etc.)
_____Additional Benefits (Food production, etc.)
_____Other: *Please List:*_____

8. Is there anything I have not asked that you wish to discuss?

Stakeholder Survey (Version 2)

1. Do you own or rent?

2. What does the term 'pollinator garden' mean to you? How would you describe pollinator garden?

3. Do you have a pollinator garden? If yes, what were some of the obstacles you encountered when installing the garden? If no, please skip to question 4.

4. Of the following, what would be the three biggest obstacles for installing pollinator garden?

   Please rank three of the following in order of importance (1=most important, 2=second most important, and 3= third most important)

_____Limited space or lack of sunlight
_____Poor aesthetics
_____Maintenance
_____Cost
_____Concern about bees, pests, or pollen allergies
_____Help with installation
_____Not enough time
_____Permission from a landlord
_____Other: *Please List:* _____

5. Of the following, what would be the three biggest motivators to install a pollinator garden?

   Please rank three of the following in order of importance (1=most important, 2=second most important, and 3= third most important)

_____Community Engagement
_____Aesthetics
_____Educational Benefits
_____Benefits to Pollinators
_____Benefits to the Environment (reduced flooding, cleaner air, etc.)
_____Additional Benefits (Food production, etc.)
_____Other: *Please List:*_____

6. Is there anything I have not asked that you wish to discuss?

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